



Sampling and Analysis Plan

Remedial Investigation/Feasibility Study West County Road 112 Ground Water Plume Site Midland, Midland County, Texas

Remedial Action Contract 2 Full Service Contract: EP-W-06-004 Task Order: 0065-RICO-A6R6

Prepared for

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27 October 2010

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LIST OF ACRONYMS

bgs	below ground surface
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COPC	contaminant of potential concern
CR	County Road
CSM	conceptual site model
DQA	data quality assessment
DQO	data quality objective
EA	EA Engineering, Science, and Technology, Inc.
EDD	electronic data deliverable
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ESI	Expanded Site Inspection
FS	Feasibility Study
FSP	Field Sampling Plan
GPS	Global Positioning System
HHRA	human health risk assessment
HSP	Health and Safety Plan
IDW	investigativion-derived waste
I-20	U.S. Interstate Highway 20
LCS	laboratory control spike
MCL	Maximum Contaminant Level
MD	matrix duplicate
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
PARCC	precision, accuracy, representativeness, completeness, and comparability
PSQ	principal study question
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAC	Remedial Action Contract
RAGS	Risk Assessment Guidance for Superfund
RI	Remedial Investigation
ROD	Record of Decision
ROW	right-of-way
RPD	relative percent difference
SAP	Sampling and Analysis Plan
Site	West County Road 112 ground Water Plume Site
SOP	standard operating procedure
SOW	Statement of Work

LIST OF ACRONYMS (CONTINUED)

TAL	Target Analyte List
TCEQ	Texas Commission on Environmental Quality
TOC	top-of-casing
TOM	Task Order Monitor
µg/L	microgram(s) per liter
USGS	U.S. Geological Survey
WCR 112	West County Road 112

DISTRIBUTION LIST

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1. PROJECT DESCRIPTION AND MANAGEMENT

EA Engineering, Science, and Technology, Inc. (EA) has been authorized by the U.S. Environmental Protection Agency (EPA), under Remedial Action Contract (RAC) Number EP-W-06-004, Task Order 0065-RICO-A6R6, to conduct a Remedial Investigation (RI)/Feasibility Study (FS) at the West County Road 112 (WCR 112) Ground Water Plume Superfund Site (Site). EA has prepared this Sampling and Analysis Plan (SAP) in accordance with specifications provided in the EPA Statement of Work (SOW), dated 26 July 2010 (EPA 2010e), and the EPA-approved EA Work Plan (Revision 01), dated 24 August 2010 (EA 2010b).

This SAP is a combination Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). It details the field sampling schedule, sample collection procedures, and analytical methods required to collect sufficient data to perform a RI/FS for the WCR 112 Site. Combining the QAPP and FSP into the SAP allows a streamlining of the planning process, while ensuring that data collected are of sufficient quality for its intended use.

This SAP was prepared in conjunction with the Health and Safety Plan (HSP) (EA 2010c), which together, present the overall approach for implementing the RI field program. The HSP specifies employee training, protective equipment, personal air monitoring procedures, medical surveillance requirements, standard operating procedures, and contingency planning procedures.

This SAP was prepared in accordance with EA's Quality Management Plan (EA 2010a) and meets requirements set forth in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operation (QA/R-5)*(EPA 2001a); *Guidance for Quality Assurance Project Plans (QA/G-5)*(EPA 2002a); and *Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)*(EPA 2006a).

This SAP describes procedures to assure that the project-specific data quality objectives (DQOs) are met, and that the quality of data (represented by precision, accuracy, completeness, comparability, representativeness, and sensitivity) is known and documented. The SAP presents the project description, project organization and responsibilities, and quality assurance (QA) objectives associated with the sampling and analytical services to be provided in support of the RI/FS. Table 1 demonstrates how this SAP complies with elements of a QAPP currently required by EPA guidance (EPA 2001a; 2002a; 2006a). Because the sampling effort for this Site is phased and each subsequent sampling effort will build upon the previous effort, Appendix A, which includes a detailed description of each of the elements specific for each phase of field operations, will be updated for each subsequent phase, as necessary.

The overall QA objectives are as follows:

- Attain quality control (QC) requirements for analyses specified in this SAP.
- Obtain data of known quality to support goals set forth for this project.

- Document aspects of the quality program including performance of the work and required changes to work at the Site.

The EPA Region 6 Task Order Monitor (TOM), Mr. Vincent Malott, is responsible for the project oversight. The Project Officer for EPA Region 6 is Ms. Rena McClurg. The Contracting Officer for EPA Region 6 is Mr. Michael Pheeny. EA will perform tasks under this Task Order in accordance with this SAP. The EA Project Manager, Ms. April Ballweg, is responsible for implementing activities required by this Task Order. Figure 1 presents the proposed project organization for this Task Order.

1.1 PROBLEM DEFINITION AND BACKGROUND

This section describes the following:

- Purpose of the investigation and sampling events (Section 1.1.1)
- Site background and description (Section 1.1.2).

1.1.1 Purpose of the Investigation and Sampling Events

The purpose of this investigation is to collect ground water, surface soils, subsurface soils, and other ancillary data to support a RI/FS. The RI/FS process will allow the EPA to determine the source area(s) for one or more ground water contaminant plumes and select a remedy that eliminates, reduces, or controls risks to human health and the environment. The goal is to develop the minimum amount of data necessary to support the selection of an approach for site remediation and then to use these data to result in a well-supported Record of Decision. The EPA RI/FS SOW (EPA 2010e) and EPA-approved Work Plan (EA 2010b) set forth the framework and requirements for this effort.

1.1.2 Site Background and Description

The WCR 112 Site is situated in Midland County within and south of the Midland, Texas, city limits, and north and south of U.S. Interstate Highway 20 (I-20) (Figure 2). The Site consists of ground water impacted with chromium originating from an unidentified source area(s). The plume has been tentatively mapped south of I-20; however, Site boundaries are currently established as illustrated in Figure 3 (also see Appendix B, Conceptual Site Model [CSM]).

The plume(s) has been specifically identified south of I-20. This area is a mix of residential, commercial, industrial, and agricultural properties (Texas Commission on Environmental Quality [TCEQ] 2010a, 2010b). The plume, as currently understood, extends 1 to 1.5 miles southeast of I-20. The eastern and western boundaries have been identified based on the available analytical data. Ground water is the sole source of potable water in this area. The contaminant plume(s) has impacted private residential wells and supply wells that serve residences, commercial/industrial properties, and agricultural concerns. The TCEQ has installed filtration systems on those private wells with concentrations greater than the EPA Maximum Contaminant Level (MCL) for total chromium of 100 micrograms per liter (µg/L). The contamination has been detected in the shallow Ogallala Formation and deeper Edwards-Trinity

Aquifer at depths ranging from 50-100 feet below ground surface (bgs), based on a review of private water well logs. Ground water flow appears to be from northwest to south-southeast based on contaminant distribution.

Appendix B contains a detailed description of the geology and hydrogeology of the area underlying the Site.

1.2 DESCRIPTION OF PROJECT OBJECTIVES AND TASKS

This section describes the project objectives and tasks for this SAP.

1.2.1 Project Objectives

The primary objectives of the RI/FS are to determine the nature and extent of contamination and to gather sufficient information so that the EPA can select a remedy that eliminates, reduces, or controls risks to human health. Specifically, the RI/FS involves multimedia environmental sampling of the WCR 112 Site. In order to meet these objectives, field data collection activities will be implemented in a phased manner, such that data collection is cost-effective and logically sequenced to focus each subsequent investigation task. Specific sampling details for Phase 1 of this RI are presented in Appendix A. Following is a comprehensive list of the field activities under this RI:

- **Ground Water Sampling**—EA will collect ground water samples from existing private water supply wells, existing monitoring wells, and newly-installed monitoring wells. Samples will be analyzed for Target Analyte List (TAL) metals, hexavalent chromium, and/or other parameters, as directed by EPA.
- **Monitoring Well Installation**—EA will install and develop up to 60 ground water monitoring wells at 30 locations to evaluate ground water and provide additional information regarding the horizontal and vertical distribution of chromium within the Ogallala Formation and Edwards-Trinity Aquifer. Well locations will be subject to a utility location service evaluation prior to installation. Newly-installed wells will be surveyed to provide top-of-casing (TOC) elevations. In addition, EA will install and develop up to 20 ground water monitoring wells at approximately 10 locations that will be used to evaluate ground water during the aquifer and/or pilot testing.
- **Geophysical Logging**—EA will coordinate geophysical logging on open boreholes prior to the construction of the new wells at approximately 40 locations. In addition, up to approximately 15 existing wells will be geophysically logged. Wells will be logged using gamma and resistivity logging instruments.
- **Ground-Water-Level Data Collection**—EA will collect continuous water-level-gauging data using data-logger probes with a pressure transducer and temperature sensor in selected private wells, contingent on the provision of access agreements. Pumping data from local water wells and local rainfall data may also be collected, as available.

- **Aquifer Testing**—EA will conduct aquifer testing to evaluate hydrogeologic conditions within the Ogallala Formation and Edwards-Trinity Aquifer. EA will collect continuous water monitoring data using approximately 20 data-logging probes, each having a pressure transducer and temperature sensor. Pumping data from local water wells and local rainfall data may also be collected as available.
- **Soil Sampling**—EA will conduct soil sampling to characterize soil contaminant concentrations and additional parameters that may be required for remedy evaluation/selection. Once a potential source area is identified, soil samples will be collected from the surface to either: the bottom of impacted soil, native soil below source material, or to 10 feet bgs, which is generally considered the deepest depth interval for risk assessment. Soil samples will be analyzed for TAL metals and hexavalent chromium, as well as any other parameters, as directed by EPA. Soil samples will also be collected from select intervals to be batch tested in a soil testing laboratory to determine distribution (K_d) of hexavalent chromium in soil and aquifer matrix to evaluate soil-leaching-to-ground water, contaminant seepage velocities, fate and transport modeling, and cleanup alternatives.

1.2.2 Project Tasks

To complete the RI/FS activities at the WCR 112 Site, EA will perform the following tasks (with subtasks), which are generally outlined in the Task Order SOW (EPA 2010e) and detailed in Sections 2, 3, and 4 of this SAP.

- Project planning and support
- Field investigation/data acquisition
- Sample analysis
- Analytical support and data validation
- Data evaluation
- Risk assessment
- Treatability Study/Pilot Testing
- RI Report
- Remedial alternatives screening and evaluation
- FS Report
- Post-RI/FS support.

EA's field activities will be conducted in accordance with this SAP to ensure proper sample management, including accurate chain-of-custody procedures for sample tracking, protective sample packaging techniques, and proper sample preservation techniques. The requirements of EA's site-specific HSP (EA 2010c) will be followed. Sample management will be conducted using the EPA-approved FORMS II Lite software.

EA will perform investigative-derived waste (IDW) characterization and disposal in accordance with local, state, and federal regulations; IDW will be subject to disposal, as appropriate.

1.3 DATA QUALITY OBJECTIVES

The following sections present the DQOs for this project. Much of the information used to develop DQOs was obtained from the SOW issued by the EPA (2010e) and the EPA-approved Work Plan (EA 2010b). The CSM developed for the WCR 112 Site is included as Appendix B and summarizes the current understanding of the sources of contamination, pathways of exposure, and receptors at the Site and outlines the data gaps that will be addressed by this SAP. The CSM also forms the basis for the DQO assessment.

This DQO assessment follows EPA's 7-step DQO process (Table 2), which is outlined in *Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)* (EPA 2006a). Additional information is referenced, as appropriate, in the following sections.

- Section 1.3.1—Purpose and Goal
- Section 1.3.2—Step 1 – State the Problem
- Section 1.3.3—Step 2 – Identify the Goal of the Study
- Section 1.3.4—Step 3 – Identify Information Inputs
- Section 1.3.5—Step 4 – Define the Boundaries of the Study
- Section 1.3.6—Step 5 – Develop the Analytical Approach
- Section 1.3.7—Step 6 – Specify the Performance or Acceptance Criteria
- Section 1.3.8—Step 7 – Develop the Plan for Obtaining Data.

1.3.1 Purpose and Goal of DQO Process

The purpose of defining DQOs for the WCR 112 Site is to create a systematic planning framework to support the final decision whether the site poses a threat to the human health and the environment and as such requires a remedial action or not. The data collected will be adequate for the development of the FS, under which alternative remediation options are evaluated. The DQOs goal is to develop a body of data that are defensible and are collected in an effective and efficient manner.

1.3.2 Step 1 – State the Problem

The first step in systematic planning process and, therefore, the DQO process, is to define the problem that has initiated the study. As environmental problems are often complex combinations of technical, economic, social, and political issues, it is critical to the success of the process to separate each problem, define it completely, and express it in an uncomplicated format (Table 2).

The most important activities in DQO Step 1 are as follows:

- Give a concise description of the problem
- Identify leader and members of the planning team
- Develop a CSM of the environmental hazard to be investigated
- Determine resources (i.e., budget, personnel, and schedule).

1.3.2.1 Problem Description

A residential well ground water sampling program has been undertaken since 2009 when local residents contacted TCEQ. Initial sampling identified multiple private wells screened in the Ogallala Formation and Edwards-Trinity Aquifer with chromium concentrations greater than the MCL. TCEQ responded by installing water treatment systems in 45 homes. Ground water flow in the area is from northwest to southeast. As such, TCEQ completed an Expanded Site Inspection (ESI) that focused on three sites northwest of the original WCR 112 Site, including Schlumberger Technology Corporation, B&W Welding and Construction, and the Williamson Gravel Pit, to determine if any of these facilities were the source of chromium in ground water. During this investigation, chromium at concentrations greater than the MCL was detected in the shallow Ogallala Formation. Chromium was also identified in ground water within the deeper Edwards-Trinity Aquifer, but at concentrations below the MCL. Based on the results of the ESI, TCEQ classified the Site as a ground water plume with no identified source.

Broadly defined, the WCR 112 Site is bounded between I-20 to the northwest and County Road (CR) 124 to the southeast, and between CR 1210 to the southwest and CR 1193 to the northeast (Figure 1). Ground water collected from potable water wells in this area has been impacted by chromium at concentrations greater than the EPA MCL of 100 µg/L for total chromium. More than 40 households with impacted private water supplies have been equipped with filtration systems supplied by TCEQ. The EPA has only established MCLs for total chromium and not for the hexavalent chromium fraction of total chromium. Though upgradient ground water and soil sampling to evaluate potential sources of ground water impacts was completed as part of the ESI, the source of the chromium plume was not determined. The Site has been classified as a ground water plume with no identified source. Potential unacceptable risk to human health receptors as a result of exposure to contaminants of potential concern (COPCs) in Site-related media (i.e., air, soil, or ground water) has not been estimated. The CSM (see Appendix B) identifies the primary COPC for the Site as chromium.

1.3.2.2 Planning Team Members and Stakeholders

Involvement by a team of experts and stakeholders at the very beginning of the planning process is essential to resolve the problem. The planning team members (including the leader) and stakeholders are presented below.

Planning Team Members

- Vincent Malott, EPA TOM
- Danielle Sattman-Soule, TCEQ Project Manager
- EPA RAC Contractor, EA.

Stakeholders

- EPA Region 6 Superfund Division Management
- EPA Headquarters
- TCEQ Remediation Division

- City of Midland and citizenry
- Other interested parties.

If additional planning team members and/or stakeholders are identified as the RI/FS progresses, they will be incorporated into the decision-making process, as appropriate.

1.3.2.3 Develop the Conceptual Site Model

It is critical to carefully develop an accurate CSM of the environmental problem, as this model will serve as the basis for subsequent inputs and decisions. The CSM is presented in Appendix B.

1.3.2.4 Determine Resources

Resources should be identified by the planning team so that constraints (e.g., budget, time, etc.) associated with collecting/evaluating data can be anticipated during the project life cycle. EPA has tasked EA to assist with the development of the planning documents for this RI, perform the investigation, and prepare the deliverables required for the completion of the RI/FS. EA will utilize the services of various subcontractors to implement the planned activities. For data analysis, EA will utilize the EPA's Region 6 Laboratory, EPA Contract Laboratory Program (CLP), TCEQ Houston Laboratory, or a private laboratory, selecting the appropriate laboratory depending on the needs of the RI/FS and the availability of services.

The EPA will perform a review of each required deliverable and provide comments as necessary. EPA will also solicit comments from other planning team members or stakeholders as appropriate. Additional details pertaining to the schedule of events and deliverables necessary to meet the RI/FS milestones were provided in the RI/FS Work Plan (EA 2010b).

1.3.3 Step 2 – Identify the Goal of the Study

Step 2 of the DQO process involves identifying the key questions that the study attempts to address, along with alternative actions or outcomes that may result based on the answers to these key questions. These two items are combined to develop a decision statement, which is critical for defining decision performance criteria later in Step 6 of the DQO process.

The most important activities in DQO Step 2 are as follows.

- Identify principal study question(s).
- Consider alternative actions that can occur upon answering the question(s).
- Develop decision statement(s) and organize multiple decisions.

1.3.3.1 Principal Study Question

The principal study question(s) (PSQ) define the question(s) to be answered during the RI using the exposure risks from the human health risk assessment (HHRA) and ecological risk assessment (ERA). The PSQs are as follows:

- *What are the nature and extent (including sources) of chromium contamination in ground water and soil?*
- *What are the fate and migration pathways for chromium to be transported?*
- *Is there a potential risk to human health and ecological receptors from exposure to chromium that will require a remedy implementation?*

1.3.3.2 Alternative Actions

The alternative actions provide PSQ alternatives in the FS as follows. Potential alternative actions, which will be evaluated in the FS, include, but are not limited to, the following:

- *Remediate the source areas.*
- *Mitigate the ground water migration pathways.*
- *Prevent exposure to chromium in ground water by installing (point-of-use) ground water filtration systems.*
- *Address other migration/exposure pathways impacting receptors by employing engineering or institutional controls.*

1.3.3.3 Decision Statement

For decision-making problems, the PSQs and alternative actions are combined to develop decision statements that are critical for defining decision performance criteria later in DQO Step 6.

The decision statements are as follows:

- *Determine the nature and extent (including sources) of chromium contamination in ground water and soil.*
- *Determine the fate and migration pathways for chromium to be transported.*
- *Determine if exposure to chromium poses a potential unacceptable risk to human health and ecological receptors.*

1.3.4 Step 3 – Identify Information Inputs

Step 3 of the DQO process determines the types and sources of information needed to resolve: (1) the decision statement or produce the desired estimates; (2) whether new data collection is necessary; (3) the information basis the planning team will need for establishing appropriate analysis approaches and performance or acceptance criteria; and (4) whether appropriate sampling and analysis methodology exists to properly measure environmental characteristics for addressing the problem.

The most important activities in DQO Step 3 are as follows:

- Identify types and sources of information needed to resolve decisions or produce estimates
- Identify the basis of information that will guide or support choices to be made in later steps of the DQO process
- Select appropriate sampling and analysis methods for generating the information.

The EPA RI/FS SOW (EPA 2010e) and EPA approved Work Plan (EA 2010b) set forth the framework and requirements for this effort.

1.3.4.1 Identify Necessary Information and Sources

The sources and types of information form the basis for resolving the decision statements. The following information and sources are necessary to resolve this step of the DQO process.

The decision statements are supported by the following:

- ***Determine the nature and extent (including sources) of chromium contamination in ground water and soil.***
 - An evaluation of previous investigation data was conducted in the CSM (Appendix B); this data shaped the field investigation by narrowing or broadening the data needs. Previous investigations to determine the source(s) of hexavalent chromium appear to have ruled out sources, but have not identified the source area(s). Therefore, additional analysis needs to be completed to identify the contaminant source(s) so remedial actions can be completed. These data will also be subject to further evaluation in the RI.
 - Additional ground water and soil data will be collected to augment the historical dataset.
 - Geologic and hydrogeologic information, coupled with physical/chemical property data, will be collected to evaluate the impacts to vadose zone soil, Ogallala Formation, and Edwards-Trinity Aquifer.

- ***Determine the fate and migration pathways for chromium to be transported.***
 - An evaluation of the ground water flow regime will be conducted to aid in understanding the transport of contamination into the Ogallala Formation and Edwards-Trinity Aquifer.
 - If identified, an evaluation of source material leaching to ground water will be completed through the collection and evaluation of vadose zone source area data.
 - Soil from the vadose zone and aquifer matrix will be laboratory tested to establish K_d , evaluate soil-leaching-to-groundwater pathway, and estimate retardation of contaminant seepage.
- ***Determine if exposure to chromium poses a potential unacceptable risk to human health and ecological receptors.***
 - The areas in the vicinity of the source areas and downgradient of the source areas will be evaluated for potential human health and ecological exposure pathways.

1.3.4.2 Basis of Information

The basis of information will guide or support choices to be made in later steps of the DQO process.

The basis of information is supported by the following:

- ***Determine the nature and extent (including sources) of chromium contamination in ground water and soil.***
 - Biased or judgmental sample locations will be based on evaluation of historical data, photographs, or visual cues.
 - An evaluation of previous investigation data will utilize EPA guidance documents including, but not limited to: Guidance for Data Usability in Risk Assessment (EPA 1992); Data Quality Assessment - Statistical Methods for Practitioners (EPA 2006c); Guidance for Data Quality Assessment (EPA 2000); Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA 2006a).
 - Geologic and hydrogeologic information coupled with physical/chemical property data will be collected to evaluate the impacts to the Ogallala Formation and Edwards-Trinity Aquifer.

- ***Determine the fate and migration pathways for chromium to be transported.***
 - The Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA 1988) describes the process for evaluating migration pathways.
- ***Determine if exposure to chromium poses a potential unacceptable risk to human health and ecological receptors.***
 - A HHRA will be conducted in accordance with EPA guidance which includes, but is not limited to, the following:
 - Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (EPA 1989)
 - RAGS for Superfund Volume I: Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors (EPA 1991)
 - RAGS, Volume I, Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments (EPA 2001b)
 - Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (EPA 2002b)
 - Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Interim Guidance (EPA 2002c)
 - RAGS, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (EPA 2004a).
 - A Screening Level ERA will be conducted in accordance with the EPA's guidance which includes, but is not limited to, the following:
 - RAGS, Volume II: Environmental Evaluation Manual (EPA 1997a)
 - Ecological RAGS: Process for Designing and Conducting Ecological Risk Assessments (EPA 1997b, 1999).

1.3.4.3 Sampling and Analysis Methods

An extensive field investigation has been proposed to collect soil and ground water data. Details pertaining to this effort are contained in Section 2.0.

1.3.5 Step 4 – Define the Boundaries of the Study

In Step 4 of the DQO process, the target population of interest and spatial/temporal features pertinent for decision making should be identified. The most important activities in DQO Step 4 are as follows.

- Define the target population of interest.
- Specify temporal or spatial boundaries and other practical constraints associated with sample/data collection.

1.3.5.1 Target Population

The source area(s) of the chromium impacts have not been identified. TCEQ data led them to conclude that the source of ground water impacts are located between the B&W Welding facility located north of I-20 and the I-20 corridor (Figure 1). Vadose zone soil, Ogallala Formation ground water, and Edwards-Trinity Aquifer ground water are the focus of the investigation.

The target population consists of soil and ground water in proximity to and downgradient of the vadose zone source areas. The following subsections discuss the temporal and spatial boundaries of these target populations.

1.3.5.2 Spatial Boundaries

The horizontal study boundary for the Site RI/FS includes the areal extent of the chromium contaminant plume. The estimated center of the site is situated in Midland County, 2 blocks south of I-20 in the southwest quadrant of the I-20 and the Cotton Flat Road intersection, which is located south of the City of Midland, Texas. The extent of known ground water impacts encompasses an area of approximately 260 acres (TCEQ 2010a; 2010b). Data collected during the investigation, as well as information regarding historical use, presence of chromium, potential reuse, available receptors, etc., may indicate this areal extent needs to be expanded during the RI.

The horizontal study boundary for the site RI/FS includes the potential source area that is subject to investigation for the site. The TCEQ has indicated that the potential source area is southeast of the B&W Welding facility near the I-20 corridor. It is possible that additional areas may be discovered pending further investigation and additional information regarding historical use, presence of contaminants, potential reuse, available receptors, etc.

The Ogallala Formation is the upper most water-bearing unit in the vicinity of the site. Ogallala ground water is routinely utilized as a water supply, for watering lawns, washing vehicles, or other non-drinking water uses. The deeper Edwards-Trinity Aquifer is a ground water source aquifer for west Texas; private and municipal wells utilize the Edwards-Trinity Aquifer for domestic use (e.g., drinking water). The City of Midland primary water supply is Lake Ivie. However, the city has a backup public water supply well field, the Paul Davis field, located 30 miles north of Midland. Underlying the Edwards-Trinity Aquifer is the Triassic Dockum

Formation, colloquially “Red Beds,” consisting of interbedded substantial sequences shale and sandstone water-bearing zones. The shale beds form confining layers; thus, the Red Beds mark the vertical domain of the ground water investigation.

The temporal extent of the investigation is defined as the duration of the RI activities. Please refer to Appendix D for the project schedule.

1.3.5.3 Temporal Boundaries

Generally soil is not considered temporally variant within the time constraints of performing the RI. Neither the hydrogeologic characteristics nor the spatial distribution of contaminants in soil is considered time-dependant. Therefore, time-series of soil samples are not required; a single sampling of a target interval will be considered representative to support pathway analysis and risk assessment.

Ground water, however, represents a target where time variability of data is a factor. It is reasonable to assume that over the course of the RI, concentration trends at a point (e.g., monitoring well) may vary, or that in space (as represented by plume migration), concentrations may vary. Therefore, collection of time-series data for ground water is specified to ensure that variability in data as a function of time is accounted for in all decision-making related to RI data.

1.3.6 Step 5 – Develop the Analytical Approach

Step 5 of the DQO process involves developing an analytic approach that will guide how to analyze the study results and draw conclusions from the data. It is the intention of this step to integrate the outputs from the previous four steps with the parameters developed in this step. The most important activities in DQO Step 5 are as follows.

- Specify the appropriate population parameters for making decisions.
- Choose a workable action level and generate an “If ... then ... else” decision rule which involves it.

1.3.6.1 Population Parameters

The population parameter is defined as the value used in the decision statement to evaluate a decision point. The population parameter will be used as an exposure point concentration in the HHRA. A population parameter will be determined for each chemical (e.g., chromium) in each exposure area (e.g., in the vicinity of 2604 West County Road 112) for each sample group (e.g., shallow ground water). In this example, the population is chromium in the vicinity of 2604 West County Road 112 shallow ground water. The population parameter for site comparisons will be the 95-percent Upper Confidence Limit of the Mean, which will be calculated using ProUCL version 4.00.04 (EPA 2009), or the maximum detected concentration, if lower.

1.3.6.2 Action Level Decision Rule

The action levels for the Site will likely be either: (1) risk-based screening criteria developed during the HHRA or Screening Level ERA; or (2) federally mandated ground water criteria such as MCLs.

The following risk-based screening criteria were used to evaluate whether analytical data will be of sufficient quality for risk assessment.

Human Health

- Soil – Residential and Industrial Regional Screening Levels for Chemical Contaminants at Superfund Sites (Oak Ridge National Laboratory [ORNL] 2008)
- Ground Water – Tap Water Screening Levels for Chemical Contaminants at Superfund Sites (ORNL 2008) or MCLs (EPA 2010a). The Regional Screening Level for hexavalent chromium in tap water is 0.043 µg/L (EPA 2010d); the MCL for total chromium is 100 µg/L (EPA 2010a).

Ecological

- Soil – EPA Ecological Soil Screening Levels (EPA 2010d); ORNL Preliminary Remediation Goals (ORNL 2008).

Mineral or chemical interference may lead to elevated sample quantitation limits, which are greater than their respective risk-based screening values. If these analytes are not detected in an exposure area and sample quantitation limits are greater than risk-based values, then they may be a source of potential risk underestimation or additional sampling may be conducted to mitigate the uncertainty.

The decision rule for the Site is as follows:

- If Site concentrations are less than risk-based criteria, then a risk evaluation is generally not recommended.
- Otherwise, if Site concentrations are greater than risk-based criteria, then a risk evaluation is warranted.

1.3.7 Step 6 – Specify the Performance or Acceptance Criteria

Step 6 of the DQO process specifies the tolerable limits on decision errors. Data are subject to various types of errors (e.g., analytical error, how samples were collected, how measurements were made, etc.). As a result, estimates or conclusions that are made from the collected data may deviate from what is actually true within the population. Therefore, there is a chance that an erroneous conclusion could be made or that the uncertainty in the estimates will exceed what is acceptable.

The data performance or acceptance criteria will be derived to minimize the possibility of either making erroneous conclusions or failing to keep uncertainty in estimates to within acceptable levels. Performance criteria and QA practices will guide the design of new data collection efforts. Acceptance criteria will guide the design of procedures to acquire and evaluate existing data.

The most important activities in DQO Step 6 are as follows:

- Recognizing the total study error and devising mitigation techniques to limit error.
- Specify the decision rule as a statistical hypothesis test, examine consequences of making incorrect decisions from the test, and place acceptable limits on the likelihood of making decision errors.

1.3.7.1 Total Study Error

Even though unbiased data collection methods may be used, the resulting data will still be subject to random and systematic errors at different stages of the collection process (e.g., from field sample collection to sample analysis). The combination of these errors is called the “total study error” (or “total variability”) associated with the collected data. There can be many contributors to total study error, but there are typically two main components, sampling error and measurement error.

Sampling Error

Sampling error, sometimes called statistical sampling error, is influenced by the inherent variability of the population over space and time, the sample collection design, and the number of samples collected. It is usually impractical to measure the entire population space, and limited sampling may miss some features of the natural variation of the measurement of interest. Sampling design error occurs when the data collection design does not capture the complete variability within the population space, to the extent appropriate for making conclusions. Sampling error can lead to random error (i.e., random variability or imprecision) and systematic error (bias) in estimates of population parameters. In general, sampling error is much larger than measurement error and consequently needs a larger proportion of resources to control.

Measurement Error

Sometimes called physical sampling error, measurement error is influenced by imperfections in the measurement and analysis protocols. Random and systematic measurement errors are introduced in the measurement process during physical sample collection, sample handling, sample preparation, sample analysis, data reduction, transmission, and storage.

The potential for measurement error will be mitigated by using accurate measurement techniques. As described in Sections 2.3 and 2.4, sampling techniques were selected to limit the measurement error, including the following:

- Sample collection, sample processing, and any field-based analysis will be performed using standard operating procedures (SOPs). Field QC samples will be collected and analyzed to evaluate consistency in field operations, as well as interference of outside factors on data quality. Field QC samples are specified in Section 2.12.1.
- Laboratory sample processing and analyses will be performed using the laboratory's SOPs, and in accordance with the laboratory's Quality Assurance Plan. Laboratory QC samples will be prepared and analyzed, and will serve to validate the analytical results. This will ensure that the methodology remains consistent and limits the potential for measurement error. Laboratory QC samples are specified in Section 2.12.2.

1.3.7.2 Statistical Hypothesis Testing and Decision Errors

Decision-making problems are often transformed into one or more statistical hypothesis tests that are applied to the collected data. Data analysts make assumptions on the underlying distribution of the parameters addressed by these hypothesis tests, in order to identify appropriate statistical procedures for performing the chosen statistical tests.

Due to the inherent uncertainty associated with the collected data, the results of statistical hypothesis tests cannot establish with certainty whether a given situation is true. There will be some likelihood that the outcome of the test will lead to an erroneous conclusion (i.e., a decision error).

When a decision needs to be made, there are typically two possible outcomes: either a given situation is true, or it is not. Although it is impossible to know whether an outcome is really true, data are collected and statistical hypothesis testing is performed to make an informed decision. In formulating the statistical hypothesis test, one of the two outcomes is labeled the "baseline condition" and is assumed to represent the *de facto*, true condition going into the test, and the other situation is labeled the "alternative condition." The baseline condition is retained until the information (data) from the sample indicates that it is highly unlikely to be true.

The statistical theory behind hypothesis testing allows for defining the probability of making decision errors. However, by specifying the hypothesis testing procedures during the design phase of the project, the performance or acceptance criteria can be specified.

There are four possible outcomes of a statistical hypothesis test. Two of the four outcomes may lead to no decision error; there is no decision error when the results of the test lead to correctly adopting the true condition, whether it is the baseline or the alternative condition. The remaining two outcomes represent the two possible decision errors. The first is a false rejection decision error, which occurs when the data leads to decision that the baseline condition is false when, in reality, it is true. The second is a false acceptance decision error, which occurs when the data are insufficient to change the belief that the baseline condition is true when, in reality, it is false.

In the statistical language of hypothesis testing, the baseline condition is called the "null hypothesis" (H_0) and the alternative condition is called the "alternative hypothesis" (H_a). A false rejection decision error, or a Type I error, occurs when you reject the null hypothesis when it is actually true. The probability of this error occurring is called alpha (α) and is called the

hypothesis test's level of significance. A false acceptance decision error, or a Type II error, occurs when you fail to reject the null hypothesis when it is actually false. The probability that this error will occur is called beta (β). Frequently, a false rejection decision error is the more severe decision error, and therefore, criteria placed on an acceptable value of alpha (α) are typically more stringent than for beta (β). Statisticians call the probability of rejecting the null hypothesis when it is actually false the statistical power of the hypothesis test. Statistical power is a measure of how likely the collected data will allow you to make the correct conclusion that the alternative condition is true rather than the default baseline condition and is a key concept in determining DQOs for decision-making problems. Note that statistical power represents the probability of "true rejection" (i.e., the opposite of false acceptance) and, therefore, is equal to $1-\beta$.

Decision errors can never be totally eliminated when performing a statistical hypothesis test. However, the primary aim of this step is to arrive at the upper limits on the probabilities of each of these two types of decision errors that the planning team finds acceptable.

The null hypothesis is the mean concentration of a contaminant does exceed (i.e., is greater than or equal to) the action level and the alternative hypothesis is the mean concentration does not exceed the action level as follows:

$$H_0 = \text{Mean Media Analyte Concentration} \geq \text{Action Level}$$

$$H_a = \text{Mean Media Analyte Concentration} < \text{Action Level}$$

For the statistical evaluations conducted for the Site, the probability of a Type I error occurring will be established at 5 percent and a Type II error will be established at 10 percent.

The Type I error rate was set more conservatively because this type of error would result in finding the site uncontaminated when it actually was contaminated. Type I error is considered more serious than Type II error because it would leave contamination in place for continuing exposure to receptors. By comparison, a higher Type II error rate of 10 percent was tolerable because this type of error would result in considering the site contaminated when it is actually not contaminated.

1.3.8 Step 7 – Develop the Plan for Obtaining Data

In Steps 1 through 6 of the DQO process, performance or acceptance criteria were developed. The goal of Step 7 is to develop a resource-effective sampling design for collecting and measuring environmental samples, or for generating other types of information needed to address the PSQ. In addition, this sampling design will lead to data that will achieve the performance and acceptance criteria.

The most important activity in DQO Step 7 is as follows:

- Use the information from Steps 1 through 6 of the DQO process to identify a sampling and analysis design that will answer the PSQ and achieve the performance or acceptance criteria.

Normally, this step would require compiling a few different sampling and analysis designs, which could be evaluated to determine the best approach to answer the PSQ and achieve the performance or acceptance criteria. However, the sampling and analysis design was largely dictated by the SOW issued by EPA on 26 July 2010 (EPA 2010e); the EPA-approved Work Plan Revision 1, dated 24 August 2010 (EA 2010b); and subsequent conference calls and electronic correspondence.

Ground water samples will be collected from private wells in the vicinity of the Site where impacted ground water is likely to be present; and from monitoring wells in the upgradient (e.g., in the potential source area), downgradient (to determine the extent of the plume boundary), and in the vicinity of the site where impacted ground water is likely to be present and where potential pilot studies may be completed. The soil sampling approach contains biased or judgmental samples. Soil samples will also be biased toward areas of known ground water impacts or areas where ground penetrating radar studies indicate that anomalies exist. This approach introduces bias and potential sampling error; however, the bias is of a conservative nature, the sampling program being more likely to yield higher media concentrations, which in turn, will likely result in a more protective remedial decision. A higher Type II error that is considered more protective of human health or the environment is considered to be acceptable for this evaluation.

Additional details pertaining to the sampling and analysis design are detailed throughout this document and will not be repeated here for brevity.

1.4 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

A well-defined QA/QC process is integral to the generation of analytical data of known and documented quality. The QC process includes those activities required during data collection to produce data of sufficient quality to support the decisions that will be made based on the data (e.g., decisions to be made prior to, during, and after site remedial actions) (EPA 2006a). After environmental data are collected, QA activities focus on evaluating the quality of the data in order to determine the data usability with respect to support for remedial or enforcement decisions. Table 3 presents the acceptance criteria for definitive onsite and offsite laboratory data for chemical analyses of investigation samples only.

1.4.1 Data Categories

In order to produce data suitable for decision-making, an appropriate analytical technique must be selected. The EPA Superfund program has developed two descriptive categories of analytical techniques: (1) field-based techniques; and (2) fixed-laboratory techniques. The type of data generated depends on the qualitative and quantitative DQOs developed for a project. Regardless of whether the data were analyzed utilizing field or laboratory techniques, it must be of adequate quality for the decision-making process for which it was collected. For this project, data from both types of techniques will be collected. Field measurements will include the collection of water quality parameters (e.g. temperature, pH, Eh, conductivity, turbidity, etc.). Section 2 discusses the methods that will be used to analyze the samples. Both field-based and definitive analytical data will be used to support decisions made for this project.

Rigorous analytical methods (e.g., EPA CLP methods) are used to generate analyte-specific, definitive data. The definitive quality of the data is assured by using SOP and QC processes during data collection; documented control and traceability of reference standards, calibrations, and instrument performance; and acceptable performance of field and laboratory QC procedures within the defined limits established for these procedures.

The majority of the fixed-laboratory analysis for samples collected during the RI/FS sampling event will be conducted by the EPA's Region 6 Laboratory, EPA CLP, or a private laboratory depending on the needs of the RI/FS and the availability of the laboratory's services.

1.4.2 Measurement Quality Objectives

Analytical results will be evaluated in accordance with precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters to document the quality of the data and to ensure that the data are of sufficient quality to meet the project objectives. Of these PARCC parameters, precision and accuracy will be evaluated quantitatively by collecting the QC check samples listed in Table 3.

The sections below describe each of the PARCC parameters and how they will be assessed within this project.

1.4.2.1 Precision

Precision is the degree of mutual agreement between individual measurements of the same property under similar conditions. Usually, combined field and laboratory precision is evaluated by collecting and analyzing field duplicates and then calculating the variance between the samples, typically as a relative percent difference (RPD).

RPD is calculated as follows:

$$RPD = \frac{|A - B|}{(A + B)/2} \times 100\%$$

where: A = first duplicate concentration
B = second duplicate concentration

Field sampling precision is evaluated by analyzing field duplicate samples. For every 10 samples collected, one blind duplicate sample per sample matrix will be collected. Field measurements will be calibrated each day following manufacturer recommendations prior to, and following daily field use (see Section 2.12.1). If calibration readings deviate 20 percent or more from the concentration of the calibration standard, the unit will be recalibrated.

Laboratory analytical precision is evaluated by analyzing laboratory duplicates (also called matrix duplicates [MDs]) or matrix spikes (MSs) and matrix spike duplicates (MSDs). For this project, MS/MSD and MS/MD samples will be generated for analytes. The results of the analysis of each MS/MSD or MS/MD pair will be used to calculate the RPD as a measure of lab precision. The RPD acceptance criteria are listed in Table 3.

1.4.2.2 Accuracy

A program of sample spiking will be conducted to evaluate laboratory accuracy. This program includes analysis of the MS and MSD samples, laboratory control spikes (LCSs) or blank spikes, surrogate standards, and method blanks. MS and MSD samples will be prepared and analyzed at a frequency of 5 percent per sample matrix. LCSs or blank spikes are also analyzed at a frequency of 5 percent per sample matrix. Surrogate standards, where available, are added to every sample analyzed for inorganic constituents. The results of the spiked samples are used to calculate the percent recovery for evaluating accuracy.

$$\text{Percent Recovery} = \frac{S - C}{T} \times 100\%$$

where: S = measured spike sample concentration
C = sample concentration
T = true or actual concentration of the spike

The objective for accuracy of field measurements (e.g. temperature, pH, Eh, turbidity, conductivity, etc.) is to achieve and maintain factory specifications for the field equipment. Field-portable analyzers will be calibrated using calibration standards at the start and end of each field day.

1.4.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition that they are intended to represent. For this project, representative data will be obtained through careful selection of sampling locations and analytical parameters. Representative data will also be obtained through proper collection and handling of samples to avoid interference and minimize contamination.

Representativeness of data will also be ensured through the consistent application of established field and laboratory procedures. Field blanks (if appropriate) and laboratory blank samples will be evaluated for the presence of contaminants to aid in evaluating the representativeness of sample results. Data determined to be non-representative, by comparison with existing data, will be used only if accompanied by appropriate qualifiers and limits of uncertainty.

1.4.2.4 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this SAP, and when none of the QC criteria that affect data usability are exceeded. When data validation is completed, the percent completeness value will be calculated by dividing the number of useable sample results by the total number of sample results planned for this investigation.

As discussed further in Section 4.2, completeness will also be evaluated as part of the data quality assessment process (EPA 2006b and 2006c). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

1.4.2.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units in reporting analytical data. Standard EPA analytical methods and QC will be used to support the comparability of analytical results with those obtained in other testing. Calibrations will be performed in accordance with EPA or manufacturer's specifications and will be checked with the frequency specified in the EPA CLP SOWs ILM05.4 and ISM01.2 (EPA 2004b; 2006d; 2010b).

1.4.3 Detection and Quantitation Limits

The analytical parameters and their quantitation limits for use on this project are determined under the EPA CLP SOW(s). The Contract-required Detection Limit is the minimum concentration of an analyte that can be reliably distinguished from background noise for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a sample matrix. Contract-required Quantitation Limit are contractually specified maximum quantitation limits for specific analytical methods and sample matrices, such as soil or water, and are typically several times the method detection limit (MDL) to allow for matrix effects.

For this project, analytical methods have been selected so that the Contract-required Quantitation Limit for each target analyte is below the applicable regulatory screening criteria, wherever practical. For this project, samples results will be reported as estimated values if concentrations are less than Contract-required Quantitation Limits but greater than Contract-required Detection Limits. The Contract-required Detection Limit for each analyte will be listed as the detection limit in the laboratory's electronic data deliverable (EDD).

1.5 SPECIAL TRAINING AND CERTIFICATION

This section outlines the training and certification required to complete the activities described in this SAP. The following sections describe the requirements for the EA team and subcontractor personnel working onsite.

1.5.1 Health and Safety Training

EA field team personnel who work at hazardous waste project sites are required to meet the Occupational Safety and Health Administration (OSHA) training requirements defined in 29 Code of Federal Regulations (CFR) 1910.120(e). These requirements include: (1) 40 hours of formal offsite instruction; (2) a minimum of 3 days of actual onsite field experience under the supervision of a trained and experienced field supervisor; and (3) 8 hours of annual refresher

training. Field personnel who directly supervise employees engaged in hazardous waste operations also receive at least 8 additional hours of specialized supervisor training.

Copies of the field team's health and safety training records, including course completion certifications for the initial and refresher health and safety training, and specialized supervisor training are maintained in project files.

For more health and safety details, see EA's site-specific HSP (EA 2010c).

1.5.2 Subcontractor Training

Subcontractors who work on site will certify that their employees have been trained for work on hazardous waste project sites. Training will meet OSHA requirements defined in 29 CFR 1910.120(e). Before work begins at the project site, subcontractors will submit copies of the training certification for each employee to EA.

Employees of associate and professional services firms and technical services subcontractors will attend a safety briefing and complete the Safety Meeting Sign-Off Sheet before they conduct on-site work (EA 2010c). This briefing is conducted by the EA Site Health and Safety Officer or other qualified person.

Subcontractors are responsible for conducting their own safety briefings; EA personnel may audit these briefings. Alternatively, the subcontractors may elect to attend the EA safety briefings.

1.6 DOCUMENTS AND RECORDS

The following sections discuss the requirements for documenting field activities and for preparing laboratory data packages. This section also describes reports that will be generated as a result of this project.

1.6.1 Field Documentation

Field personnel will use permanently bound field logbooks with sequentially numbered pages to record and document field activities and will follow SOP 016 (Appendix E) for completing field logbooks. The logbook will list the contract name and number; site name; and names of subcontractors, service client, and Project Manager. At a minimum, the following information will be recorded in the field logbook:

- Name and affiliation of on-site personnel or visitors
- Weather conditions during the field activity
- Summary of daily activities and significant events
- Notes of conversations with coordinating officials
- References to other field logbooks or forms that contain specific information
- Discussions of problems encountered and their resolution
- Discussions of deviations from the SAP or other governing documents
- Description of photographs taken.

1.6.2 Laboratory Documentation

This section describes the data reporting requirements for EA field personnel and laboratories (e.g., EPA CLP laboratories, EPA Region 6 laboratory, or subcontracted non-CLP laboratories) that submit field and laboratory measurement data under the EPA Region 6 RAC II program.

EA will require fixed offsite non-CLP laboratories to prepare and submit data packages in accordance with the EPA CLP protocols (EPA 2004b; 2006d; 2010b; 2010c) for hardcopy and EDD format of lead data. Data packages will include applicable documentation for independent validation of data and verification of the DQOs. The following documentation will be required for full data validation, if applicable.

- Case narratives, which will describe QC non-conformances that are encountered during the analysis of samples in addition to corrective actions that are taken:
 - Statement of samples received
 - Description of deviations from the specified analytical method
 - Explanations of data qualifiers that are applied to the data
 - Other significant problems that were encountered during analysis.
- Tables that cross-reference field and laboratory sample numbers.
- Chain-of-custody forms, which pertain to each sample delivery group or sample batch that is analyzed.
- Laboratory reports, which must show traceability to the sample analyzed and must contain specified information:
 - Project identification.
 - Field sample number.
 - Laboratory sample number.
 - Sample matrix description.
 - Dates and times of sample collection, receipt at the laboratory, preparation, and analysis.
 - Description of analytical method and reference citation.
 - Results of individual parameters, with concentration units, including second column results, second detector results, and other confirmatory results, where appropriate.
 - Quantitation limits achieved.
 - Dilution or concentration factors.
- Data summary forms and QC summary forms showing analytical results, if applicable:
 - Samples
 - Surrogates
 - Blanks
 - Field QC samples
 - LCS
 - Initial and continuing calibrations

- Other QC samples.
- Laboratory control charts:
 - Raw data
 - Instrument printouts
 - Laboratory bench sheets for preparation of samples.
- MDL study results.

EA's Project Manager, in cooperation with the QA Officer, will define site-specific requirements for data reporting. Requests for analytical services define these requirements, the turnaround time for receipt of the data deliverables specified, and requirements for retaining samples and laboratory records. Laboratory QA managers are responsible for ensuring that laboratory data reporting requirements in this SAP are met.

1.6.3 Full Data Package

When a full data package is required, the laboratory will prepare data packages in accordance with the instructions provided in the EPA CLP SOWs ILM05.4 and ISM01.2 (EPA 2004b; 2006d; 2010b; 2010c). Full data packages will contain the information from the summary data package and associated raw data. Full data packages are due to EA within 35 days after the last sample in the sample delivery group is received. Unless otherwise requested, the subcontractor will deliver one copy of the full data package.

1.6.4 Reports Generated

Following the completion of the RI field program and receipt of validated data, EA will prepare the following reports associated with the site RI/FS:

- Data Validation Report
- Data Evaluation Summary Report
- Baseline HHRA Report
- Screening-Level ERA Report
- RI Report
- Remedial Alternatives Technical Memorandum
- Remedial Alternatives Evaluation
- FS Report
- FS Addendum (if requested by EPA).

The specific requirements and elements of each of these reports are discussed in detail in the EPA-approved RI/FS Work Plan (EA 2010b).

2. DATA GENERATION AND ACQUISITION

This RI will be conducted in phases. Data generation and acquisition for each subsequent phase is based on the results of the previous phase(s). The details of the initial Phase 1 investigation to be performed under this RI are described in Appendix A of this SAP. Future RI phases will be

described in future addenda to this SAP. The associated field forms are provided in Appendix D. Additional ancillary investigatory activities are detailed in the SOPs listed in Table 4 and presented in Appendix E. This section describes the requirements for the following:

- Sampling process design (Section 2.1)
- Consent for property access (Section 2.2)
- Sampling methodology (Section 2.3)
- Sample processing (Section 2.4)
- Decontamination (Section 2.5)
- Management of investigation-derived waste (Section 2.6)
- Sample designation (Section 2.7)
- Sample container, volume, preservation, and holding time requirements (Section 2.8)
- Sample handling and custody (Section 2.9)
- Analytical methods requirements (Section 2.10)
- Quality control requirements (Section 2.11)
- Instrument calibration and frequency (Section 2.12)
- Requirements for inspection and acceptance of supplies and consumables (Section 2.13)
- Data acquisition requirements (Section 2.14)
- Data management (Section 2.15).

2.1 SAMPLING PROCESS DESIGN

For the activities associated with this Task Order and SAP, main elements of the sampling design include the numbers and types of samples to be collected, sampling locations, sampling frequencies, and sample matrices. Appendix A describing Phase I activities is included in this version of the SAP.

As stated in the DQO (Section 1.3), the following PSQs were formulated for the RI:

- ***What are the nature and extent (including sources) of chromium contamination in ground water and soil?***
- ***What are the migration pathways for chromium to be transported?***
- ***Is there a potential risk to human health and ecological receptors from exposure to chromium that will require a remedy implementation?***

The primary objective of the sampling design is to collect data of sufficient quantity and quality to resolve the PSQs and support risk assessment and remedy evaluation. The purpose of the RI/FS is to determine the nature and extent of contamination and to gather sufficient information so that the EPA can select a remedy that eliminates, reduces, or controls risks to human health or the environment, as follows:

- ***Determine the nature and extent (including sources) of chromium contamination in ground water and soil.***

- *Determine the migration pathways for chromium to be transported.*
- *Determine if exposure to chromium poses a potential unacceptable risk to human health and ecological receptors.*

The goal is to develop the minimum amount of data necessary to support the selection of an approach for the site investigation, and then to use the data to support a ROD. To achieve this goal, soil and ground water will be sampled during the RI/FS at the site.

The CSM (Appendix B) summarizes the current understanding of the site and includes a detailed list of data gaps that will be addressed by this SAP. Upon receipt of analytical and consultation with the EA and other experts, EPA prepared a SOW (EPA 2010e). EA anticipates conducting from four to six phases of environmental sampling and investigation. A preliminary project schedule is provided in Appendix D. The investigations will include the following elements:

- **Ground Water Sampling**—EA will collect tap water samples from existing private and public water supply wells and ground water samples from newly-installed monitoring wells. Samples will be analyzed for TAL metals and hexavalent chromium. Additional analyses may be performed for other parameters, as directed by EPA. Because this SAP is a living document with additional decisions regarding which wells will be sampled to be based on further analysis, lists of private wells to be sampled have not been included. The number of QC samples to be collected will be in accordance with the requirements set forth in this SAP. EA will coordinate with EPA prior to each mobilization to identify which wells are to be sampled and to ensure that the necessary access agreements are in place.
- **New Monitoring Well Installation**—EA will install and develop ground water monitoring wells to evaluate ground water and provide additional information regarding the horizontal and vertical distribution of chromium the Ogallala Formation and Edwards-Trinity Aquifer. In addition, EA will install and develop up to 20 ground water monitoring wells in approximately 10 locations that will be used to evaluate ground water during aquifer and/or pilot testing.
- **Geophysical Logging**—Geophysical logging will be conducted on open boreholes prior to the completion of newly-installed monitoring wells. In addition, existing private and public water supply wells will be geophysically logged, pending owner access and EPA technical direction. EA will subcontract with a well pump service to pull and reset pumps in existing wells. Open boreholes and existing wells will be logged using gamma and resistivity logging instruments.
- **Ground Water Data Collection**—EA will collect continuous water monitoring data using data-logger probes with a pressure transducer and temperature sensor in selected private wells, contingent on the provision of access agreements. Pumping data from local public water supply wells and private wells will be collected and compared to water level data to assess potential associated influences of pumping on the ground water flow patterns (e.g., potentiometric levels and gradients). Local rainfall data will also be

collected and compared to water level data to assess potential associated influence of recharge on the ground water flow patterns.

- **Aquifer Testing**—EA will conduct aquifer testing to evaluate hydrogeologic conditions within the Ogallala Formation and Edwards-Trinity Aquifer. An aquifer pump test or slug test will be conducted. The parameters of the aquifer testing will be developed in consultation with EPA. EA will collect continuous water monitoring data using data-logging probes, each having a pressure transducer and temperature sensor. Pumping data from local water wells and local rainfall data may also be collected, as available.
- **Soil Sampling**—EA will conduct soil sampling to characterize soil contaminant concentrations and additional parameters that may be required for remedy evaluation/selection. Once a potential source area is identified, soil samples will be collected from the surface to either: the bottom of impacted soil, native soil below source material, or to 10 feet bgs, which is generally considered the deepest depth interval for risk assessment. Soil samples will be analyzed for TAL metals and hexavalent chromium, as well as any other parameters, as directed by EPA. A subcontracted utility location service will be used in advance of sampling.

2.2 CONSENT FOR PROPERTY ACCESS

Sampling activities will be performed on privately-owned properties and multi-jurisdictional right-of-ways (ROWS) located within and south of the city of Midland, Midland County, Texas. EPA will obtain consent for property access agreements from the private property owners and applicable jurisdictions (i.e., city, county, and state) that have been identified for investigation under the RI/FS. For properties where the property owner cannot be identified and/or the property owner is not responsive, other properties may be identified for characterization, as appropriate.

2.3 STANDARD OPERATING PROCEDURES AND SAMPLING PROTOCOLS

The following sections outline the procedures for sample collection and major investigatory activities that will be applied consistently during the phased RI approach at the Site. The details of the initial Phase 1 investigation to be performed under this RI are described in Appendix A of this SAP. Future RI phases will be described in future addenda to this SAP. Additional ancillary investigatory activities are detailed in the SOPs listed in Table 4 and presented in Appendix E.

During sample collection, preparation, and field analysis, chain of custody will be maintained and documented as required in Section 2.10. Sample locations will be documented photographically and sketched in the field logbook; an accompanying photograph log will be completed in the field logbook (see Section 1.6.1). Sample collection and handling procedures for samples that will be analyzed using the CLP will follow CLP protocols in accordance with EPA's *Contract Laboratory Program Guidance for Field Samplers* (EPA 2007). QA/QC samples will be collected in accordance with protocols established in this SAP (Table 6).

EA will conduct the elements as outlined in the EPA SOW (EPA 2010f), and described in Section 2.1. Because the sampling effort is phased, and each subsequent sampling effort will

build on the previous effort, Appendix A will be updated for each phase of sampling. Appendix A will include a detailed description of each of the elements specific for each phase of sampling.

2.3.1 Ground Water Gauging and Sampling

Wells will be gauged to assist in the preparation of potentiometric surface maps at the Site. Ground water samples will be collected to support vertical and horizontal delineation of the Site ground water contaminant plume.

2.3.1.1 Monitoring Well Gauging

Monitoring wells will be gauged with an interface probe using EA SOP 010 (Appendix E). Total well depth will be measured periodically in the wells, to determine if sediment is accumulating in the well sump.

2.3.1.2 Water Supply Well Sampling

Prior to each phase-specific field mobilization, each resident or owner will be notified and provided with an approximate date and time for their well to be sampled along with documentation of special requirements by the resident or owner. EA will coordinate with EPA prior to Site mobilization to identify which wells are to be sampled and to ensure that the necessary access agreements are in place. The private and public water supply wells will be purged and geochemical parameters monitored and logged using a calibrated water quality meter in accordance with SOP 014 (Appendix E). The parameters collected will include pH, temperature, and conductivity (SOPs 008, 009, and 012) (Appendix E). These parameters will be measured for 15 minutes prior to sampling or until the readings have stabilized (conductivity within 10%, pH within plus or minus 0.5 pH unit, and temperature within plus or minus 1 °C). Measurement of field parameters is further described in SOPs 008, 009, 012, 036, 037, 038, and 048 (Appendix E). The samples will be collected from the tap located closest to the well head and prior to a connection to a water treatment/filtration system. In the case where a dedicated functioning pump is not available, ground water samples may be collected using low-flow sampling methodology (SOP 048, Appendix E). Tap water samples will be analyzed for TAL metals and hexavalent chromium (Table 5), as well as other parameters, as directed by EPA.

2.3.1.3 Monitoring Well Ground Water Sampling

Following well development, ground water samples will be collected from the newly-installed monitoring wells using snap samplers (Appendix E) or low-flow sampling methodology (SOP 048, Appendix E), or other sampling methodology. Ground water samples will be analyzed for TAL metals and hexavalent chromium (Table 5), as well as other parameters, as directed by EPA.

2.3.2 Geophysical Logging

Geophysical logging will be conducted on open boreholes prior to the completion of newly-installed monitoring wells to obtain a better understanding of geologic conditions. In addition, existing monitoring and public water supply wells will be geophysically logged, pending owner

access and EPA technical direction. EA will subcontract with a well pump service to pull and reset pumps in existing wells. Open boreholes and existing wells will be logged using gamma and resistivity logging instruments. Depending on availability, EPA will coordinate with the U.S. Geological Survey (USGS) to perform geophysical logging activities. As a contingency measure, EA will use a subcontract with a geophysical logging firm to support the investigation in the case where the USGS is unavailable.

EA will manage this effort in accordance with SOP 044 (Appendix E). EA will provide the necessary equipment and personnel to perform decontamination of these tools between well locations, and will also be responsible for the collection, characterization, and disposal of associated IDW in accordance with local, State, and Federal regulations.

2.3.3 New Monitoring Well Installation

Based on interpretation of geophysical logs from nearby wells and/or open boreholes, monitoring wells may be constructed as single or multiple (nested) completions in accordance with SOPs 003 and 019 (Appendix E), as appropriate. Nested wells will be constructed as follows:

- Nested monitoring well pairs will address two depth intervals in either the shallow (Ogallala) aquifer or the deep (Edwards-Trinity) aquifer.
- The nested monitoring well pair cluster will consist of two nested 2-inch-diameter wells within a single borehole
- A nested well pair may be grouped in close proximity to another well pair or a single well completion to provide vertical delineation across both aquifers at a single location, as follows:
 - One borehole will include two nested 2-inch-diameter wells, each screened at two different depth intervals within the Ogallala Formation (shallow aquifer).
 - Second borehole will include (1) two 2-inch-diameter wells, each screened at two different depth intervals within the Edwards-Trinity (deep aquifer); or (2) a single 4-inch-diameter well screened across a longer interval within the Edwards-Trinity (deep aquifer).

With the exception of the wells to be constructed in the suspected source areas, the deeper borehole will be drilled first. The borehole will be geophysically logged to establish the screen intervals for all nearby wells. Within suspected source areas, the shallower borehole will be drilled and geophysically logged first to avoid cross contamination of the underlying aquifer.

New monitoring wells will be developed in accordance with SOP 019 (Appendix E).

2.3.4 Ground Water Data Collection

EA will collect continuous water-level data using data-logger probes with a pressure transducer and temperature sensor in existing wells in accordance to SOP 010 (Appendix E), contingent on

the provision of access agreements. Probes shall also be installed in new wells as they are constructed and added to the monitoring program. Data will be used to develop ground water potentiometric maps for the respective water-bearing zones. Pumping data from local water wells and local rainfall data may also be collected as available.

2.3.5 Aquifer Testing

EA will conduct aquifer testing to evaluate hydrogeologic conditions within the Ogallala Formation and Edwards-Trinity Aquifer in accordance with SOP 033 (Appendix E). An aquifer pump test or slug test will be conducted. The parameters of the aquifer testing will be developed in consultation with EPA. EA will collect continuous water monitoring data using data-logging probes, each having a pressure transducer and temperature sensor. Pumping data from local water wells and local rainfall data may also be collected, as available.

2.3.6 Soil Sampling

Surface and subsurface soil samples will be collected for source delineation and HHRA. Soil samples will be collected using a slide hammer or manual soil-coring device in accordance with SOPs 025 and 047 (Appendix E). A hammer drill will be used to facilitate penetration of asphalt- and concrete-covered surfaces. A concrete coring device will be available as a contingency if the hammer drill cannot penetrate the concrete. If a layer of caliche is encountered that prevents samples from being collected, soil samples will be collected during drilling activities in subsequent phases of the investigation. A subcontracted utility location service will be used in advance of sampling.

Once a potential source area is identified, soil samples will be collected from the surface to either: the bottom of impacted soil, native soil below source material, or to 10 feet bgs, which is generally considered the deepest depth interval for risk assessment. Soil samples will be analyzed for TAL metals and hexavalent chromium (Table 5), as well as other parameters, as directed by EPA.

Subsurface soil and aquifer matrix samples will be collected and analyzed to establish distribution coefficients to support fate and transport analysis.

2.4 LAND SURVEYING

During the RI field program, EA will survey soil sample locations using portable GPS equipment. EA will also survey the locations and TOC elevations for newly-installed monitoring wells and those existing wells undergoing geophysical logging using portable GPS equipment. Elevations for each well TOC will be measured and referenced to a relative benchmark. As an alternative, EA may subcontract a local State of Texas-Registered Professional Licensed Surveyor to perform survey activities. After field activities are complete, the surveyor will draft survey maps illustrating the information collected.

Private and municipal supply wells that have not previously been surveyed may be surveyed using a GPS unit. GPS Data Attributes for each well position will be logged and include:

- Latitude and longitude
- Collector name
- Collection method
- Datum
- Maximum Positional Dilution of Precision
- GPS date and time
- Total positions collected at each well location.

2.5 SAMPLE PROCESSING

Samples for fixed laboratory analysis will be processed and packaged in accordance with the *Contract Laboratory Program Guidance for Field Samplers* (EPA 2007) and/or SOP 004 (Appendix E), as applicable.

2.6 DECONTAMINATION

Re-usable field equipment utilized during the RI/FS will be decontaminated prior to and after use in accordance with SOP 005 (Appendix E). Decontamination of field equipment will occur in buckets, plastic containers, or other similar containers with sealing lids, and the resulting fluid will be transferred to 55-gallon IDW drums staged designated staging area (Support Zone). The decontamination water will be properly sampled and disposed of following local, State, and Federal guidelines (see Section 2.7).

2.7 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

EA will incorporate best management practices of green remediation as it relates to the management of IDW. Soil from the offsite areas will be drummed, sealed, labeled, and stored at the designated staging area (Support Zone) until profiled for acceptance at an approved disposal facility (SOP 042, Appendix E). IDW soil samples will be submitted to an EA-subcontracted laboratory for disposal characterization. Landfill Disposal Restrictions will dictate sample quantities and analysis.

Decontamination water generated during well installation, ground water sampling, and equipment decontamination will be drummed, sealed, labeled, and stored at the designated staging area (Support Zone) until profiled for acceptance at an approved disposal facility (SOP 042, Appendix E). IDW water samples will be submitted to an EA-subcontracted laboratory for disposal characterization. The nature of the analysis will be based on the requirements of disposal facility.

2.8 SAMPLE DESIGNATION

Each sampling location will be designated with a unique alphanumeric designation according to the following sample classifications:

- **Surface and Subsurface Soil**—Soil sample designation will include four fields that are separated by dashes; for example: SS-A10-0-2.

- The first field, “SS” denotes that the samples are soil samples.
- The second field will be assigned an alphanumeric location number based on an x-y grid system alphabetically increasing from north to south and numerically increasing from west to east (e.g., Row A, Column 10), that is associated with the soil sample location.
- The third field, “0,” represents the top of the sample interval measured in feet bgs.
- The fourth field, “2,” represents the bottom of the sample interval measured in feet bgs.
- **Tap Water Sample Designation**—Tap water sample designation for private and municipal wells will utilize the well designations presented in the CSM (Appendix B). Two fields will be separated by dashes; for example: GW-001.
 - The two alpha characters in the first field, “GW,” identifies that the sample came from a permanent private or municipal ground water well as identified by the TCEQ .
 - The second field, “001,” represents the ground water well number designation or identifier.
- **New Monitoring Well Designation**—Newly-constructed monitoring well designation will include three fields that are separated by dashes; for example: MW-101-TA.
 - The two alpha characters in the first field, “MW,” identifies that the sample came from a permanent monitoring well.
 - The second field, “101,” represents the monitoring well number designation or identifier (numbering system for newly-constructed monitoring wells will begin with 100).
 - The third field, “TA,” represents the water-bearing zone in which the well is screened, where:
 - OF = Ogallala Formation
 - TA = Trinity Aquifer
 - EA may opt to add two additional fields to describe the top and bottom depth of the screen interval.
- **Monitoring Well Ground Water Sample Designation**—Ground water sample designation for monitoring wells will also utilize will include four fields that are separated by dashes (see below); for example: MW-01-TA-60.
 - The first three fields will utilize the monitoring well designations presented above.
 - The fourth field will identify the sample depth (e.g., depth at which the snap sampler or submersible pump is set).
- **Field Duplicate Sample Designation**—Field duplicate samples will be identified by adding a “D” to the end of the sample designations described above; for example, GW-001-D.
- **MS/MSD Sample Designation** (for organic analysis)—MS and MSD samples will be identified by adding an “MS/MSD” to the end of the sample designations described above; for example, GW-001-MS/MSD.

- **MS/MD Sample Designation** (for inorganic analysis)—MS and MD samples will be identified by adding an “MS/MD” to the end of the sample designations described above; for example, GW-001-MS/MD.
- **Field, Trip, and Equipment Rinsate Blank Sample Designation**—Trip and equipment blank samples will be identified sequentially beginning with TB-1, FB-1, and ER-1, respectively.

2.9 SAMPLE CONTAINER, VOLUME, PRESERVATION, AND HOLDING TIME REQUIREMENTS

Table 5 specifies the required sample volume, container type, preservation technique, and holding time for each analysis that is to be conducted during each phase of sampling. Required containers, preservation techniques, and holding times for field QC samples, such as field duplicates, will be the same as for investigative samples, but may require additional volumes as described in Section 2.11.

2.10 SAMPLE HANDLING AND CUSTODY

Each sample collected by the EA field team will be traceable from the point of collection through analysis and final disposition to ensure sample integrity. Sample integrity helps to ensure the legal defensibility of the analytical data and subsequent conclusions. Sample handling will follow CLP protocols as required in EPA’s *Contract Laboratory Program Guidance for Field Samplers* (EPA 2007).

The EA field team will use EPA’s data management system known as “FORMS II Lite” to generate chain-of-custody records in the field. Applicable copies of generated FORMS II Lite files will be delivered to EPA data management personnel as required by CLP protocols.

2.11 ANALYTICAL METHODS REQUIREMENTS

The source of analytical services to be provided will be determined in part by DQOs and the intended use of the resulting data. EA will use EPA-approved methods for laboratory analyses of the samples.

EA will follow the analytical services request procedures that are outlined EA’s Analytical Services Delivery Plan (EA 2005). If an analytical system fails, the QA officer will be notified, and corrective action will be taken. In general, corrective actions will include stopping the analysis, examining instrument performance and sample preparation information, and determining the need to re-prepare and reanalyze the samples.

Laboratories that are subcontracted by EA or EPA will conduct definitive laboratory analysis of samples. Table 5 lists the laboratory analytical methods for this project. In cases, appropriate methods of sample preparation, cleanup, and analyses are based on specific analytical parameters of interest, sample matrices, and required quantitation limits. The following sections briefly discuss each analytical method and required modifications for definitive investigative analyses.

Analyses for the IDW profiling will be conducted according to the specifications in the selected analytical method listed in Table 5.

The source of analytical services to be provided will be determined in part by DQOs and the intended use of the resulting data. EA will use EPA-approved methods for laboratory analyses of the samples.

2.11.1 Field Analytical Methods

Water quality parameters that include pH, temperature, specific conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity will be monitored using field-based methods during the collection of ground water samples. EA will follow manufacturer-recommended procedures for operating field equipment.

2.11.2 Fixed-Laboratory Analytical Methods

Fixed-laboratory analyses will be conducted by EPA's Region 6 Laboratory, EPA CLP, or a private laboratory depending on the needs of the RI/FS and the availability of the laboratory's services. Samples submitted to the analytical laboratory will be analyzed in accordance with CLP SOWs ILM05.4 and ISM01.2 (EPA 2004b; 2006d; 2010b). Modifications to analytical methods that may be required to manage atypical matrices or to achieve low quantitation limits are not anticipated. Decisions regarding the use and type of method modifications will be made during the procurement of laboratories, as different laboratories have equipment and SOPs that generate varying quantitation limits.

2.12 QUALITY CONTROL REQUIREMENTS

Various field and laboratory QC samples and measurements will be used to verify that analytical data meet the QA objectives. Field QC samples and measurements will be collected to assess the influence of sampling activities and measurements on data quality. Similarly, laboratory QC samples will be used to assess how the laboratory's analytical program influences data quality. This section describes the QC samples that are to be analyzed during the site sampling activities for: (1) each field and laboratory environmental measurement method; and (2) each sample matrix type. Table 3 shows the acceptance criteria for each type of QC sample, and Table 6 presents the frequency of QC samples to be collected at the site.

2.12.1 Field Quality Control Requirements

Field QC samples will be collected and analyzed to assess the quality of data that are generated by sampling activities. These samples will include laboratory QC samples collected in the field, field duplicates, equipment rinsates, MS/MSDs, MDs, and temperature blanks. QC samples collected in the field for fixed-laboratory analysis are presented in Table 6.

Field duplicates are independent samples that are collected as close as possible, in space and time, to the original investigative sample. Field duplicates can measure the influence of sampling and field procedures on the precision of an environmental measurement. They can also

provide information on the heterogeneity of a sampling location. Field duplicates will be collected at a frequency of one for every 10 investigative samples, as listed in Table 6. Immediately following collection of the original sample, the field duplicates are collected using the same collection method.

Equipment rinsate blanks are collected when nondedicated or nondisposable sampling equipment is used to collect samples and put the samples into containers. These blanks assess the cleanliness of the sampling equipment and the effectiveness of equipment decontamination. Equipment rinsate blanks are collected by pouring analyte-free water over the decontaminated surfaces of sampling equipment that contacts sampling media. Equipment rinsate blanks are collected after sampling equipment has been decontaminated, but before the equipment is reused for sampling. If nondedicated or nondisposable equipment is used, equipment rinsate blanks will be collected in accordance with the frequency listed in Table 6.

MS/MSD samples are laboratory QC samples that are collected for organic methods; MS/MD samples are collected for inorganic methods. For aqueous samples, MS/MSDs require double or triple the normal sample volume, depending on analytical laboratory specifications; MS/MDs require double the normal sample volume. In the laboratory, MS/MSD and MS/MD samples are split and spiked with known amounts of analytes. Analytical results for MS/MSD and MS/MD samples are used to measure the precision and accuracy of the laboratory's organic and inorganic analytical programs, respectively. Each of these QC samples will be collected and analyzed at a frequency of one for every 20 investigative samples for CLP laboratories or subcontract non-CLP laboratories, or in accordance with the requirements of the EPA Region 6 Laboratory.

Temperature blanks are containers of deionized or distilled water that are placed in each cooler shipped to the laboratory. Their purpose is to provide a container to test the temperature of the samples in the respective cooler.

2.12.2 Laboratory Quality Control Requirements

Laboratories that perform analytical work under this project must adhere to a QA program that is used to monitor and control laboratory QC activities. Each laboratory must have a written QA manual that describes the QA program in detail. The laboratory QA manager is responsible for ensuring that laboratory internal QC checks are conducted in accordance with EPA methods and protocols, the laboratory's QA manual, and the requirements of this SAP.

Many of the laboratory QC procedures and requirements are described in EPA-approved analytical methods, laboratory method SOPs, and method guidance documents.

The EPA methods specify the preparation and analysis of QC samples, and may include, but are not limited to, the following types: (1) LCSs; (2) method blanks; (3) MS, MSD, and MD samples; (4) surrogate spikes; and (5) standard reference materials or independent check standards. The following subsections discuss the QC checks that will be required for this project.

2.12.2.1 Laboratory Control Sample

LCSs are thoroughly characterized, laboratory-generated samples that are used to monitor the laboratory's day-to-day performance of analytical methods. The results of LCS analyses are compared to well-defined laboratory control limits to determine whether the laboratory system is in control for the particular method. If the system is not in control, corrective action will be implemented. Appropriate corrective actions will include stopping the analysis, examining instrument performance or sample preparation and analysis information, and determining whether samples should be re-prepared or reanalyzed.

2.12.2.2 Method Blanks

Method blanks, which are also known as preparation blanks, are analyzed to assess the level of background interference or contamination in the analytical system and the level that may lead to elevated concentration levels or false positive data. Method blanks will be required for laboratory analyses and will be prepared and analyzed at a frequency of one method blank per every 20 samples or one method blank per batch, if the batches consist of fewer than 20 samples.

A method blank consists of reagents that are specific to the analytical method and are carried through every aspect of the analytical procedure, including sample preparation, cleanup, and analysis. The results of the method blank analysis will be evaluated in conjunction with other QC information to determine the acceptability of the data generated for that batch of samples. Ideally, the concentration of a target analyte in the method blank will be below the reporting limit for that analyte. For some common laboratory contaminants, a higher concentration may be allowed.

If the method blank for analysis is beyond control limits, the source of contamination must be investigated, and appropriate corrective action must be taken and documented. This investigation includes an evaluation of the data to determine the extent of the contamination and its effect on sampling results. If a method blank is within control limits but analysis indicates a concentration of analytes that is above the reporting limit, an investigation should be conducted to determine whether corrective action could eliminate an ongoing source of target analytes.

For organic and inorganic analyses, the concentration of target analytes in the method blank must be below the reporting limit for that analyte for the blank to be considered acceptable. An exception may be made for common laboratory contaminants (such as methylene chloride, acetone, 2-butanone, and phthalate esters) that may be present in the blank at up to five times the reporting limit. These compounds are frequently detected at low levels in method blanks from materials that are used to collect, prepare, and analyze samples for organic parameters.

2.12.2.3 Matrix Spikes

MSs and MSDs are aliquots of an environmental sample for organic analysis to which known concentrations of target analytes and compounds have been added. The MS is used to evaluate the effect of the sample matrix on the accuracy of the analysis. If there are many target analytes, they will be divided into two to three spike standard solutions. Each spike standard solution will

be used alternately. The MS, in addition to an unspiked aliquot, will be taken through the entire analytical procedure, and the recovery of the analytes will be calculated. Results will be expressed in terms of percent recoveries and RPD. The percent recoveries of the target analytes and compounds are calculated and used to determine the effects of the matrix on the precision and accuracy of the method. The RPD between the MS and MSD results is used to evaluate method precision.

The MS/MSD is divided into three separate aliquots, two of which are spiked with known concentrations of target analytes. The two spiked aliquots, in addition to an unspiked sample aliquot, are analyzed separately, and the results are compared to determine the effects of the matrix on the precision and accuracy of the analysis. Results will be expressed as RPD and percent recovery and compared to control limits that have been established for each analyte. If results fall outside control limits, corrective action will be performed.

2.12.2.4 Laboratory (Matrix) Duplicates

MDs, which are also called laboratory duplicates, are prepared and analyzed for inorganic analyses to assess method precision. Two aliquots of sample material are taken from the sample and processed simultaneously without adding spiking compounds. The MD and the original sample aliquot are taken through the entire analytical procedure, and the RPD of the duplicate result is calculated. Results are expressed as RPD and are compared to control limits that have been established for each analyte.

2.12.2.5 Surrogate Spikes

Surrogates are organic compounds that are similar to the analytes of interest in chemical properties but are not normally found in environmental samples. Surrogates are added to field and QC samples, before the samples are extracted, to assess the efficacy of the extraction procedure and to assess the bias that is introduced by the sample matrix. Results are reported in terms of percent recovery. Individual analytical methods may require sample reanalysis based on surrogate criteria.

The laboratory will use surrogate recoveries mainly to assess matrix effects on sample analysis. Obvious problems with sample preparation and analysis (such as evaporation to dryness or a leaking septum) that can lead to poor surrogate spike recoveries must be eliminated before low surrogate recoveries can be attributed to matrix effects.

2.12.3 Common Data Quality Indicators

This section describes how QA objectives for precision, accuracy, completeness, and sensitivity are measured, calculated, and reported.

2.12.3.1 Precision

Precision of many analyses is assessed by comparing analytical results of MS and MSD sample pairs for organic analyses, field duplicate samples, laboratory duplicate samples (MDs), and field

replicate measurements. If precision is calculated from two measurements, it is normally measured as RPD. If precision is calculated from three or more replicates, relative standard deviation is calculated.

2.12.3.2 Accuracy

The accuracy of many analytical methods is assessed by using the results of MS and MSD samples for organic analyses, MS samples for inorganic analyses, surrogate spike samples, LCSs, standard reference materials, independent check standards, and measurements of instrument responses against zero and span gases.

For measurements in which spikes are used, percent recovery will be calculated.

2.12.3.3 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this SAP, and when none of the QC criteria that affect data usability are exceeded.

When data validation is completed, the percent completeness value will be calculated by dividing the number of useable results by the total number of sample results planned for this investigation.

Completeness will also be evaluated as part of the data quality assessment (DQA) process (EPA 2006b; 2006c). This evaluation will help determine whether limitations are associated with the decisions to be made based on the data collected.

2.12.3.4 Sensitivity

The achievement of MDLs depends on instrument sensitivity and matrix effects. Therefore, it is important to monitor the instrument sensitivity to ensure data quality and to ensure that analyses meet the QA objectives that have been established for sensitivity.

2.12.4 Instrument and Equipment Testing, Inspection, and Maintenance Requirements

This section outlines testing, inspection, and maintenance procedures for field equipment and instruments and for laboratory instruments.

2.12.4.1 General Requirements

Testing, inspection, and maintenance methods and frequency will be based on the type of instrument; the instrument's stability characteristics; the required accuracy, sensitivity, and precision of the instrument; the instrument's intended use, considering project-specific DQOs; manufacturer's recommendations; and other conditions that affect measurement or operational control. For most instruments, preventive maintenance is performed in accordance with procedures and schedules recommended in the instrument manufacturer's literature or operating manual, or SOPs associated with particular applications of the instrument.

In some cases, testing, inspection, and maintenance procedures and schedules will differ from the manufacturer's specifications or SOPs. This can occur when a field instrument is used to make critical measurements or when the analytical methods that are associated with a laboratory instrument require more frequent testing, inspection, and maintenance.

2.12.4.2 Field Equipment and Instruments

Leased field equipment and instruments will be used to conduct sampling. The vendor will be responsible for thoroughly checking and calibrating field equipment and instruments before they are shipped or transported to the field. Copies of testing, inspection, and maintenance procedures will be shipped to the field with the equipment and instruments.

After the field equipment and instruments arrive in the field, they will be inspected for damage. Damaged equipment and instruments will be replaced or repaired immediately. Battery-operated equipment will be checked to ensure full operating capacity; if needed, batteries will be recharged or replaced.

Following use, field equipment will be decontaminated properly before being returned to the source. When the equipment is returned, copies of field notes regarding equipment problems will be included so that problems are not overlooked and necessary equipment repairs are performed.

2.12.4.3 Laboratory Instruments

Laboratories that analyze samples collected under the EPA Region 6 RAC II program must have a preventive maintenance program that addresses: (1) testing, inspection, and maintenance procedures; and (2) the maintenance schedule for each measurement system and required support activity. This program is usually documented by a SOP for each analytical instrument that is to be used. Typically, the program will be laboratory specific; however, it should follow requirements outlined in EPA-approved guidelines. Some of the basic requirements and components of such a program are as follows:

- As a part of its QA/QC program, each laboratory will conduct a routine preventive maintenance program to minimize instrument failure and other system malfunction.
- An internal group of qualified personnel will maintain and repair instruments, equipment, tools, and gauges. Alternatively, manufacturers' representatives may provide scheduled instrument maintenance and emergency repair under a repair and maintenance contract.
- The laboratory will perform instrument maintenance on a regularly scheduled basis. The scheduled service of critical items should minimize the downtime of the measurement system. The laboratory will prepare a list of critical spare parts for each instrument. The laboratory will request the spare parts from the manufacturer and will store the parts.

- Testing, inspection, and maintenance procedures described in laboratory SOPs will be performed in accordance with manufacturer's specifications and the requirements of the specific analytical methods that are used.
- Maintenance and service must be documented in service logbooks (or the site-specific logbook) to provide a history of maintenance records. A separate service logbook should be kept for each instrument; however, due to the limited scope of this project, the service records will be maintained in the site-specific field logbook. Maintenance records will be traceable to the specific instrument, equipment, tool, or gauge.
- The laboratory will maintain and file records that are produced as a result of tests, inspections, or maintenance of laboratory instruments. These records will be available for review by internal and external laboratory system audits that are conducted under the EPA Region 6 RAC II program.

2.13 INSTRUMENT CALIBRATION AND FREQUENCY

This section describes the procedures for maintaining the accuracy of field equipment and laboratory instruments that are used for field tests and laboratory analyses. The equipment and instruments should be calibrated before each use or, when not in use, on a scheduled periodic basis.

2.13.1 Field Equipment

EA will perform calibration of field equipment during the field activities specified herein. Calibration of the field equipment (e.g., multi-parameter water quality meter) will be conducted on a daily basis following manufacturer recommendations, and will be performed prior to sample analysis activities. Should water quality readings appear to be questionable during sample analysis, EA will recalibrate the equipment as deemed necessary. The equipment calibration procedures described below will be followed.

Equipment will be maintained and calibrated with sufficient frequency and in such a manner that the accuracy and reproducibility of results are consistent with the manufacturer's specifications and with project-specific DQOs. Upon arrival of the field equipment, EA field personnel will examine it to verify that it is in good working condition. The manufacturer's operating manual and instructions that accompany the equipment will be consulted to ensure that calibration procedures are followed. Measuring and testing equipment may be calibrated either internally—by using in-house reference standards, or externally, by agencies, manufacturers, or commercial laboratories. Calibration records will contain a reference identifying the source of the procedure and, where feasible, the actual procedure. Each piece of measuring and testing equipment will also be accompanied by an equipment use log. The equipment use log (which may be contained within the site-specific field logbook) will be kept current and may contain the following information: date of use; times of use; operating and assisting technicians; calibration status; and comments.

2.13.2 Laboratory Instruments

Laboratory equipment that is used to analyze samples collected under the EPA Region 6 RAC II program will be calibrated on the basis of written SOPs that are maintained by the laboratory. Calibration records (including the dates and times of calibration and the names of the personnel performing the calibration) will be filed at the location at which the analytical work was performed and maintained by the laboratory personnel who performed QC activities. Subcontractor laboratories may conduct laboratory work under the EPA Region 6 RAC II program. The laboratory QA manager is responsible for ensuring that laboratory instruments are calibrated in accordance with the requirements of this SAP.

The laboratories will follow the method-specific calibration procedures and requirements for laboratory measurements. Calibration procedures and requirements will also be provided, as appropriate, for laboratory support equipment, such as balances, mercury thermometers, pH meters, and other equipment that is used to take chemical and physical measurements.

2.14 REQUIREMENTS FOR INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The EA Project Manager is responsible for identifying the types and quantities of supplies and consumables that are needed for collecting the samples for this Task Order. The Project Manager is also responsible for determining acceptance criteria for these items. When supplies are received, the EA field personnel will check packing slips against purchase orders and inspect the condition of supplies before the supplies are accepted for use on a project. If the supplies do not meet the acceptance criteria, deficiencies will be noted on the packing slip and purchase order. Afterward, the item will be returned to the vendor for replacement or repair.

2.15 DATA ACQUISITION REQUIREMENTS (NON-DIRECT MEASUREMENTS)

For this project, EA anticipates acquiring data from non-direct measurements such as databases, spreadsheets, and literature files.

2.16 DATA MANAGEMENT

A comprehensive data management program has been designed to assure that multiple information sources will result in similar data sets and data management practices will be adequate for the types of data processing required by a task order. Site team members will follow these protocols to assure results will have uniform units of measure, analytical methods, and reporting forms.

Data for this project will be obtained from a combination of sources, including: field measurements, EPA's Region 6 Laboratory, EPA CLP, or a private laboratory depending on the needs of the RI/FS and the availability of the laboratory's service. The data gathering process requires a coordinated effort and will be conducted by project staff members in conjunction with potential data producers. The data will be obtained from the analytical service provider, when appropriate, in the form of an EDD, in addition to the required hard copy analytical data

package. Formal verification (or validation) of data will be conducted before associated results are presented or are used in subsequent activities.

Data tracking is essential to ensure timely, cost effective, and high quality results. Data tracking begins with sample chain of custody. When the analytical service provider receives custody of the samples, the provider will send a sample acknowledgment to EA. The sample acknowledgment will confirm sample receipt, condition, and required analyses. The EPA tracking software (Forms II Lite) will contain pertinent information about each sample and can track the data at each phase of the process. The tracking software carries the data through completion of the data validation.

EA will validate 10 percent of the investigative analytical data received from subcontract laboratories (other than the EPA Region 6 Laboratory or CLP laboratories) to ensure that the confirmatory data are accurate and defensible. A partial review will be conducted on the remaining 90% of the data received from subcontract laboratories. Data will be evaluated for usability by EA in accordance with EPA CLP guidelines for data review (EPA 2010c).

As a part of the data validation process, EDDs will be reviewed against hard copy deliverables to ensure accurate transfer of data. In addition, the hard copy will be evaluated for errors in the calculation of results. After the data validation, qualifiers can be placed on the data to indicate the usability of the data. These qualifiers will be placed into an electronic data file. Upon approval of the data set with the appropriate data qualifiers, the electronic data will be released to the Project Manager for reporting.

3. ASSESSMENT AND OVERSIGHT

This section describes the field and laboratory assessments that may be conducted during this project, the individuals responsible for conducting assessments, corrective actions that may be implemented in response to assessment results, and how quality-related issues will be reported to EA and EPA.

3.1 ASSESSMENT AND RESPONSE ACTIONS

Under the EPA Region 6 RAC II program, performance and system audits of field and laboratory activities may be conducted to verify that sampling and analysis are performed in accordance with the following:

- Performance and system audits
 - Audit personnel,
 - Audit scope of work,
 - Audit frequencies, and
 - Audit reports;
- Corrective action
 - Sample collection and field measurements, and
 - Laboratory analyses.

Nonconforming items and activities are those that do not meet the project requirements, procurement document criteria, and approved work procedures. Nonconformance may be detected and identified by the following personnel:

- Project personnel—During field operations, supervision of subcontractors, and field inspections.
- Testing personnel—During preparation for and performance of tests, equipment calibration, and QC activities.
- QA personnel—During the performance of audits, surveillance, and other QA activities.

Each nonconformance that affects quality will be documented by the person who identifies or originates the nonconformance. Documentation of nonconformance will include the following components.

- Description of nonconformance.
- Identification of personnel who are responsible for correcting the nonconformance and, if verification is required, for verifying satisfactory resolution.
- Method(s) for correcting the nonconformance (corrective action) or description of the variance granted.
- Proposed schedule for completing corrective action and the corrective action taken.

Nonconformance documentation will be made available to the Project Manager, QA Manager, and subcontractor (e.g., non-CLP subcontract laboratories) management personnel, as appropriate.

The field personnel and QA personnel, as appropriate, are responsible for notifying the Project Manager and the QA manager of the nonconformance. In addition, the Project Manager and the project staff, as appropriate, will be notified of significant nonconformances that could affect the results of the work. The Project Manager is responsible for determining whether notification of EPA is required.

The completion of corrective actions for significant nonconformances will be documented by QA personnel during future auditing activities. Significant recurring nonconformance will be evaluated by project and QA personnel, as appropriate, to determine its cause. Appropriate changes will be instituted, under corporate or project procedures, to prevent recurrence. When such an evaluation is performed, the results will be documented.

3.2 REPORTS TO MANAGEMENT

Effective management of environmental data collection operations requires timely assessment and review of measurement activities. It is essential that open communication, interaction, and feedback be maintained among project participants, including the EA QA Manager, Program

Manager, Project Manager, technical staff, and laboratory subcontractors; and the EPA Region 6 TOM and QA Officer.

During the RI field program, EA will prepare reports that summarize the following elements:

- Work progress since the last report.
- Site observations, problems, and decisions.
- Problems that may impede planned progress.
- Safety-related observations, incidents, or potential safety problems and the corrective action(s) taken to mitigate the problem(s).
- Corrective measures and procedures to regain the planned schedule, if required.
- Work scheduled for the next work period.

If the EA field team encounters any significant problems or issues during the field program, they will immediately contact the EA Project Manager. The EA Project Manager will then immediately notify the EPA TOM and EA Program Manager. The EA Program Manager will then contact the EPA Project Officer and Contracting Officer.

EA prepares monthly progress reports for each Task Order that is conducted under the EPA Region 6 RAC II program. These reports address QA issues that are specific to the Task Order and facilitate timely communication of such issues.

At the program level, the QA Manager prepares quarterly status reports of QA issues that are related to EA's work on the EPA Region 6 RAC II program. These reports are distributed to EA's President, Corporate QA Manager, RAC II Program Manager, and, upon request, the EPA Region 6 Project Officer. QA status reports address the following areas.

- Results of QA audits and other inspections, including quality improvement; opportunities that have been identified for further action.
- Instrument, equipment, or procedural problems that affect QA.
- Subcontractor performance issues.
- Corrective actions.
- Status of previously reported activities and quality improvement initiatives.
- Work planned for the next reporting period.

4. DATA VALIDATION AND USABILITY

This section describes the procedures that are planned to review, verify, and validate field and laboratory data. Procedures for verifying that the data are sufficient to meet DQOs and measurement quality objectives for the project are also discussed. Section 4.1 focuses on data review and reduction requirements for work conducted under the EPA Region 6 RAC II program. Section 4.2 addresses data validation and verification requirements. Section 4.3 addresses reconciliation with DQOs.

4.1 DATA REVIEW AND REDUCTION REQUIREMENTS

Data reduction and review are essential functions for preparing data that can be used effectively to support project decisions and DQOs. These functions must be performed accurately and in accordance with EPA-approved procedures and techniques. Data reduction includes computations and data manipulations that produce the final results that are used during the investigation. Data review includes procedures that field or laboratory personnel conduct to ensure that measurement results are correct and acceptable in accordance with the QA objectives that are stated in this SAP. Field and laboratory measurement data reduction and review procedures and requirements are specified in previously discussed field and laboratory methods, SOPs, and guidance documents.

Field personnel will record, in a field logbook and/or on the appropriate field form, raw data from chemical and physical field measurements (SOP 016, Appendix E). The EA field staff has the primary responsibility for verifying that field measurements were made correctly; confirming that sample collection and handling procedures specified in this project-specific SAP were followed; and ensuring that field data reduction and review procedures requirements are followed. The EA field staff is also responsible for assessing preliminary data quality and for advising the data user of potential QA/QC problems with field data. If field data are used in a project report, data reduction methods will be fully documented in the report.

The EPA Region 6 Laboratory, CLP laboratory, and/or subcontracted non-CLP laboratory will complete data reduction for chemical and physical laboratory measurements and will complete an in-house review of laboratory analytical results. The laboratory QA manager will be responsible for ensuring that laboratory data reduction and review procedures follow the requirements that are stated in this SAP. The laboratory QA manager will also be responsible for assessing data quality and for advising the EA QA Manager of possible QA/QC problems with laboratory data.

4.2 VALIDATION AND VERIFICATION METHODS

Data that are used to support activities under the EPA Region 6 RAC II program must be valid for their intended purposes. This section outlines the basic data validation procedures that will be followed for field and laboratory measurements. The following sections identify personnel who are responsible for data validation and the general data validation process and EPA data validation guidance that will be followed.

4.2.1 Data Validation Responsibilities

When analytical services are provided by laboratories subcontracted by EA, EA is responsible for data validation. The QA Manager has primary responsibility for coordinating EA's data validation activities. EA will conduct full validation on 10 percent of subcontracted laboratory data for investigation samples. Partial validation will be conducted on the remaining 90 percent of subcontracted laboratory data. Data validation and review will be completed by one or more experienced data reviewers. When data are generated by the EPA Region 6 Laboratory, it will be used as received from the laboratory, with no further validation. Data from CLP laboratories are validated by EPA's Environmental Services Assistance Team.

4.2.2 Data Validation Procedures

The validity of a data set is determined by comparing the data with a predetermined set of QC limits. EA data reviewers will conduct a systematic review of the data for compliance with established QC limits (such as sensitivity, precision, and accuracy), on the basis of spike, duplicate, and blank sampling results that are provided by the laboratory. The data review will identify out-of-control data points or omissions. EA data reviewers will evaluate laboratory data for compliance with the following information:

- Method and project-specific analytical service requests
- Holding times
- Initial and continuing calibration acceptance criteria
- Field, trip, and method blank acceptance criteria
- Surrogate recovery
- Field duplicates and MS and MSD acceptance criteria
- MD precision
- LCS accuracy
- Other laboratory QC criteria specified by the method or on the project-specific analytical service request form
- Compound identification and quantitation
- Overall assessment of data, in accordance with project-specific objectives.

EA will follow the most current EPA CLP guidelines (EPA 2010c) for completing data validation for applicable test methods. General procedures in the CLP guidelines will be modified, as necessary, to fit the specific analytical method that is used to produce the data. In

cases, data validation requirements will depend on DQO levels that are defined in Section 1.3; reporting requirements that are defined in Section 1.4; and data deliverables that are requested from the laboratory, as discussed in Section 1.6.

4.3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The main purpose of a QA system is to define a process for collecting data that are of known quality, are scientifically valid, are legally defensible, and fully support decisions that will be based on the data. To achieve this purpose, the SAP requires that DQOs be fully defined (Section 1.3). Other parts of the QA system must then be planned and implemented in a manner that is consistent with the DQOs. QA system components that follow directly from the DQOs include documentation and reporting requirements (Section 1.6), sample process design and sampling methods requirements (Sections 2.1 through 2.9), analytical methods and analytical service requests (Section 2.10), QC requirements (Section 2.11), and data reduction and validation and reporting methods (Sections 4.1 and 4.2).

After environmental data have been collected, reviewed, and validated, the data will undergo a final evaluation to determine whether the DQOs specified in this SAP have been met. EA will follow EPA's DQA process to verify that the type, quality, and quantity of data that are collected are appropriate for their intended use (EPA 2006b and 2006c).

The DQA process involves verifying that the data have met the assumptions under which the data collection design and DQOs were developed, taking appropriate corrective action if the assumptions have not been met, and evaluating the extent to which the data support the decision that must be made so that scientifically valid and meaningful conclusions can be drawn from the data. To the extent possible, EA will follow DQA methods and procedures that have been outlined by EPA (EPA 2006b and 2006c).

Following the conclusion of the RI field program and receipt of fixed-laboratory data, the data evaluation will include:

- Data usability evaluation and field QA/QC—The usability of the laboratory analytical data in terms of the CLP data validation summaries and field QA/QC will be evaluated.
- Data Reduction and Tabulation—Soil borings, field sampling data, and analytical results will be reduced and tabulated.
- DESR—A DESR will be submitted that documents and summarizes the analytical data collected during this RI/FS, including the data quality and usability as related to the site-specific DQOs. The DESR shall also include previous data collected during previous site investigations (if made available) for statistical comparisons to the data collected during the RI/FS. Field QA/QC results will be summarized in context with fixed-laboratory sample results.

EA will compile analytical and field data into a format that is compatible with EPA Region 6 or National Electronic Data Management Network. EA will use the data to prepare the: Data

Validation Report; DESR; Baseline HHRA Report; Screening-Level ERA Report; RI Report; Remedial Alternatives Technical Memorandum; Remedial Alternatives Evaluation; FS Report; and FS Addendum (if requested by EPA), as well as to support the ROD. The specific requirements and elements of each of these reports are discussed in detail in the EPA-approved RI/FS Work Plan (EA 2010b).

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Figures

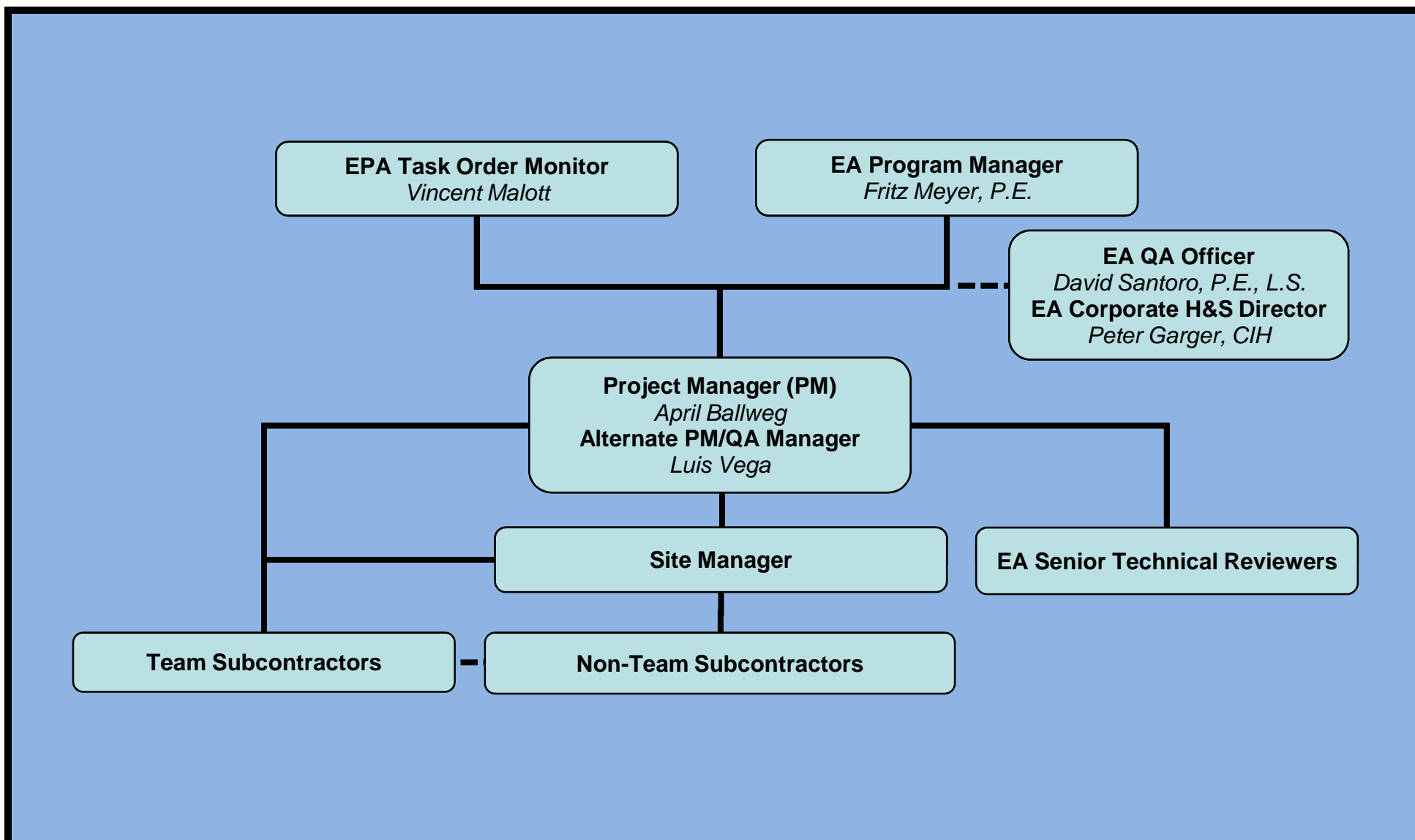


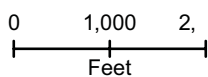
Figure 1 - Project Organization

Remedial Investigation/Feasibility Study
West County Road 112 Ground Water Plume Superfund Site
Midland County, Texas

(b) (6)



(b) (6)



(b) (6)

(b) (6)

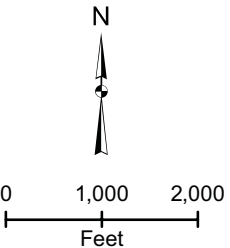
Image Source: Texas Orthoimagery Program, 2009.



Remedial Investigation/ Feasibility Study
West County Road 112
Ground Water Plume Site
Midland County, Texas

Figure 2
Site Location

(b) (6)



- Legend:**
- Business of Concern
 - Site Area



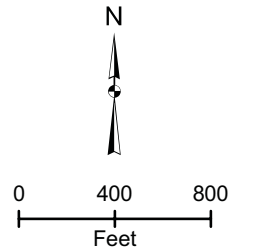
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Image Source: Texas Orthoimagery Program, 2009.







Remedial Investigation/ Feasibility Study
West County Road 112 Ground Water Plume Site
Midland County, Texas

Figure 3
Site Layout



Legend:

Monitoring Well Location

- Installed by:
-  B&W Welding
 -  Schlumberger
 -  TCEQ
 -  Unknown

Tables

TABLE 1 ELEMENTS OF EPA QA/R-5

EPA QA/R-5 QAPP Element		EA SAP (QTRAK # 08-056)
A1	Title and Approval Sheet	Title and Approval Sheet
A2	Table of Contents	Table of Contents
A3	Distribution List	Distribution List
A4	Project/Task Organization	1.0 Project Description and Management
A5	Problem Definition/Background	1.1 Problem Definition and Background
A6	Project/Task Description	1.2 Description of Project Objectives and Tasks
A7	Quality Objectives and Criteria	1.3 Data Quality Objectives 1.4 Quality Assurance Objectives for Measurement Data
A8	Special Training/Certification	1.5 Special Training and Certification
A9	Documents and Records	1.6 Documents and Records
B1	Sampling Process Design	2.1 Sampling Process Design 2.2 Consent for Property Access
B2	Sampling Methods	2.3 Sampling Methodology 2.4 Sample Processing 2.7 Sample Designation
B3	Sample Handling and Custody	2.8 Sample Container, Volume, Preservation, and Holding Time Requirements 2.9 Sample Handling and Custody
B4	Analytical Methods	2.10 Analytical Methods Requirements
B5	Quality Control	2.11 Quality Control Requirements
B6	Instrument/Equipment Testing, Inspection, and Maintenance	2.11.4 Instrument and Equipment Testing, Inspection, and Maintenance Requirements
B7	Instrument/Equipment Calibration and Frequency	2.12 Instrument Calibration and Frequency
B8	Inspection/Acceptance of Supplies and Consumables	2.13 Requirements for Inspection and Acceptance of Supplies and Consumables
B9	Non-direct Measurements	2.14 Data Acquisition Requirements (Non-Direct Measurements)
B10	Data Management	2.15 Data Management
C1	Assessment and Response Actions	3.1 Assessment and Response Actions
C2	Reports to Management	3.2 Reports to Management
D1	Data Review, Verification, and Validation	4.1 Data Review and Reduction Requirements
D2	Validation and Verification Methods	4.2 Validation and Verification Methods
D3	Reconciliation with User Requirements	4.3 Reconciliation with Data Quality Objectives

TABLE 2 DATA QUALITY OBJECTIVE PROCESS

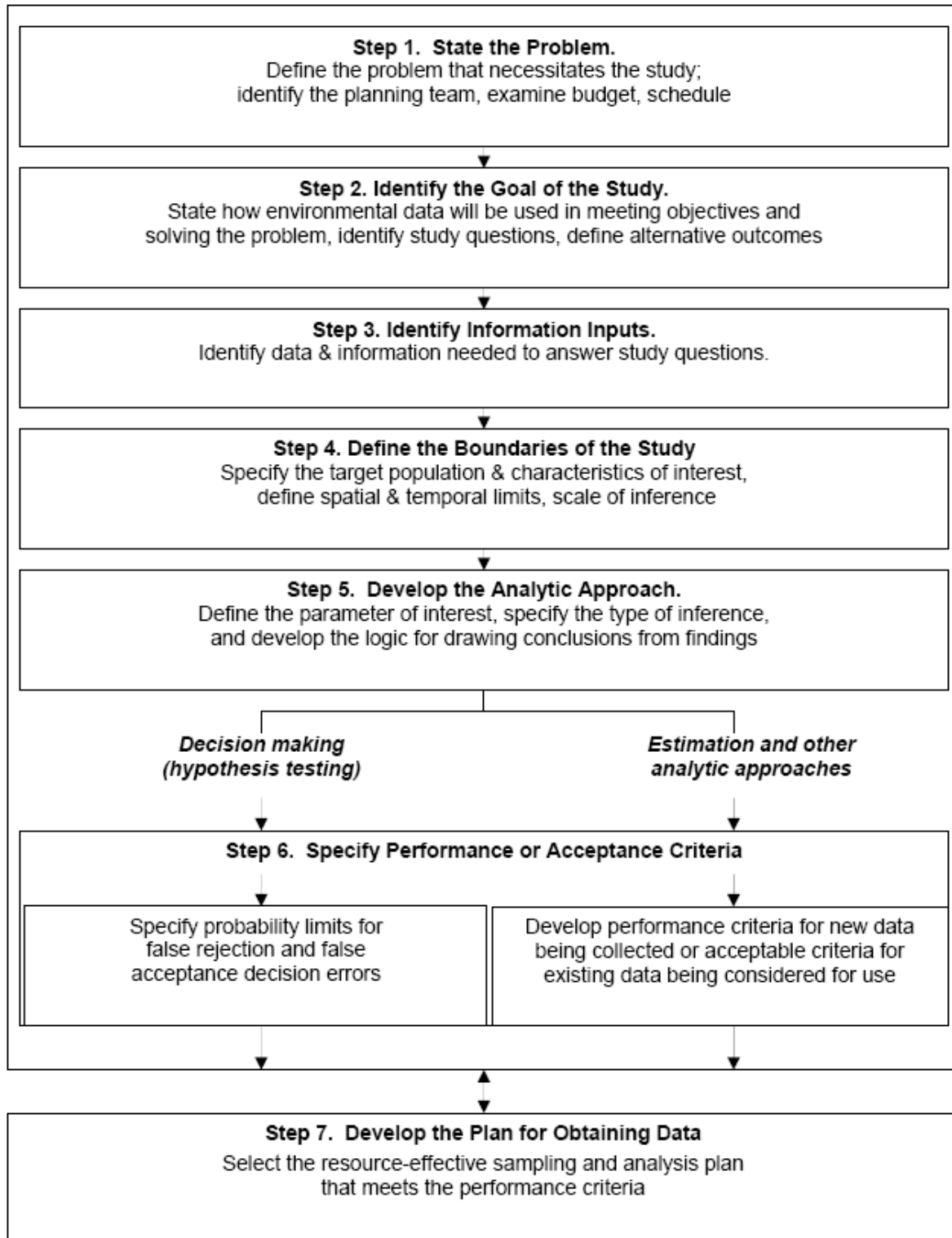


TABLE 3 QUALITY ASSURANCE INDICATOR CRITERIA

Indicator Parameter	Analytical Parameter	QC Sample	Acceptance Criteria for Laboratory Analysis
Accuracy (percent recovery)	TAL Metals Hexavalent chromium	MS	75 to 125 percent recovery
		LCS	80 to 120 percent recovery
		Blanks ¹	Less than CRDL
Precision (RPD)	TAL Metals Hexavalent chromium	MS, MD	20 percent RPD (aqueous) 35 percent RPD (solid)
		Field duplicates	50 percent RPD
Sensitivity (quantitation limits)	Analytical tests	MS, MD, MSD	Not applicable
		Field duplicates	
Completeness	The objective for data completeness is 90 percent.		
Representativeness	The sampling network analytical methods for this site are designed to provide data that are representative of site conditions.		
Comparability	The use of standard published sampling and analytical methods, and the use of QC samples, will ensure data of known quality. These data can be compared to other data of known quality.		
Notes: ¹ May include method blanks, reagent blanks, instrument blanks, calibration blanks, and other blanks collected in the field (such as field blanks) CRDL = Contract-Required Detection Limit LCS = laboratory control sample MD = matrix duplicate MS = matrix spike MSD = matrix spike duplicate QC = quality control RPD = relative percent difference TAL = Target Analyte List			

TABLE 4 STANDARD OPERATING PROCEDURES

SOP Number	SOP Title
001	Sample Labels
002	Chain-of-Custody Form
003	Subsurface/Utility Clearance
004	Sample Packing and Shipping
005	Field Decontamination
008	pH Measurement
009	Temperature Measurement
010	Water Level and Well Depth Measurements
012	Specific Conductance Measurements
013	Monitoring Well Sample Collection
014	Collection of Production Well Samples
016	Surface Water, Groundwater, and Soil/Sediment Logbooks
019	Monitoring Well Installation and Development
025	Soil Sampling
028	Well Boring and Abandonment
036	Turbidity Measurements
037	Dissolved Oxygen Measurements
038	Redox Potential Measurements
039	Sample Preservation and Container Requirements
042	Disposal of Investigation-Derived Material
044	Assessment of Existing Wells Using Downhole Geophysics
047	Direct-Push Technology Sampling
048	Low-Flow Sampling
051	Low-Flow Purge and Sampling With Dedicated Pumps
053	Concrete Coring
---	Snap Sampler® Passive Groundwater Sampling Method

**TABLE 5 REQUIRED VOLUME, CONTAINERS, PRESERVATIVES, AND
HOLDING TIMES**

Parameter	Method	Volume and Container	Preservatives	Holding Time ¹
Ground Water Samples				
TAL metals	CLP ILM05.4 or ISM01.2 ²	One 1-liter narrow-mouth HDPE bottle	Nitric acid to pH < 2 Store at 4±2°C	180 days to analysis
Hexavalent chromium	EPA SW-846 7199 ³ or equivalent	One 125-milliliter narrow- mouth HDPE bottle	Store at 4±2°C	24 hours to analysis
Soil Samples				
TAL metals	CLP ILM05.4 or ISM01.2 ²	One 8-ounce glass jar with Teflon™-lined cap	Store at 4±2°C	180 days to analysis
Hexavalent chromium	EPA SW-846 7196 ³ or equivalent	One 8-ounce glass jar with Teflon™-lined cap	Store at 4±2°C	30 days to extraction ; 7 days to analysis
Notes: ¹ Holding time is shown as the time from sample collection to the time of sample extraction/time from sample extraction to analysis (as appropriate). ² EPA 2004b; 2006d; 2010b ³ EPA 1996 CLP = Contract Laboratory Program EPA = U.S. Environmental Protection Agency HDPE = high-density polyethylene TAL = Target Analyte List				

TABLE 6 FREQUENCY OF FIELD QUALITY CONTROL SAMPLES

Field QC Sample	Frequency ¹
Field blank	1 per day, if site conditions render this sample necessary
Field duplicate	1 per 10 samples
Equipment rinsate blank	1 per non-dedicated equipment type per day or 1 per 20 samples
MS/MD ² (inorganics)	1 per 20 samples (or per EPA Region 6 Laboratory requirements)
Temperature blank	1 per cooler
Notes: ¹ The QC sample collection frequency applies to samples collected for fixed-laboratory analysis (EPA 1996; 2004b; 2006d; 2010b). ² MS and MD analyses are technically not field QC samples; however, they generally require that the field personnel collect additional volumes of samples and are, therefore, included on this table for easy reference.	

Appendix A

Phase-Specific Remedial Investigation Field Program



Phase 1 Remedial Investigation Field Program

Remedial Investigation/Feasibility Study West County Road 112 Ground Water Plume Site Midland, Midland County, Texas

Remedial Action Contract 2 Full Service Contract: EP-W-06-004 Task Order: 0065-RICO-A6R6

Prepared for

U.S. Environmental Protection Agency
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LIST OF ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
EA	EA Engineering, Science, and Technology, Inc.
EPA	U.S. Environmental Protection Agency
GPS	Global Positioning System
I-20	U.S. Interstate Highway 20
QC	quality control
RI	Remedial Investigation
ROW	right-of-way
SAP	Sampling and Analysis Plan
Site	West County Road 112 Ground Water Plume Site
TAL	Target Analyte List
TOC	top-of-casing
USGS	U.S. Geological Survey
WBZ	water-bearing zone
WCR	West County Road

1. INTRODUCTION

This Appendix details the Phase 1 Remedial Investigation (RI) field program for the West County Road (WCR) 112 Ground Water Plume Site (Site) Sampling and Analysis Plan (SAP). This Appendix will be updated for each investigative phase of the RI by the U.S. Environmental Protection Agency (EPA) and EA Engineering, Science, and Technology, Inc. (EA) using data obtained from each prior phase of the RI. This Appendix provides details specific to Phase 1 of the RI field program, such as sample types, estimated sample quantities, sample locations, sample collection methods, field procedures for borehole drilling and well installation, and the Phase 1 RI field schedule. The Quality Assurance Project Plan and Field Sampling Plan are incorporated into the main body of the SAP.

1.1 PHASE 1 ELEMENTS

The Phase 1 RI field program will include the following elements:

- Tap water sampling of private and public water supply wells
- New monitoring well installation and development
- Ground water sampling of new and existing monitoring wells
- Geophysical logging of existing private and public water supply wells and new and existing monitoring wells
- Ground water data collection.

1.2 DOCUMENT ORGANIZATION

Following this introduction, Section 2 describes the tasks to be accomplished during the Phase 1 RI field program. Section 3 presents the proposed Phase 1 RI field schedule.

2. PHASE 1 FIELD PROGRAM SAMPLING ACTIVITIES

All aspects of sample collection, the analytical program, sample handling, as well as handling quality control (QC) requirements, and data assessment are outlined in the SAP to which this field program is appended. Figures A-1, A-2, and A-3 present the sample locations for Phase 1 activities. Quality assurance and QC samples will be collected in accordance with protocols established in this SAP. Investigation-derived waste will be characterized and disposed of in the manner outlined in the SAP.

2.1 TAP WATER SAMPLING

EA will collect tap water samples from up to 120 existing private and public water supply wells for analysis. EA will coordinate with EPA prior to each mobilization to identify which wells are to be sampled and to ensure that the necessary access agreements are in place. Samples will be analyzed for Target Analyte List (TAL) metals and hexavalent chromium.

In the case of an existing water supply well with an existing non-functioning pump in place, EA will collect a ground water sample using snap samplers or low-flow sampling methodology (submersible pump). A subcontracted well pump service will have to pull and reset the existing non-functioning pump.

2.2 GEOPHYSICAL LOGGING

Geophysical logging will be conducted on open boreholes prior to the completion of newly-installed monitoring wells to obtain a better understanding of geologic conditions. In addition, existing monitoring and public water supply wells will be geophysically logged, pending owner access and EPA technical direction. Open boreholes and existing wells will be logged using gamma and resistivity logging instruments. Depending on availability, EPA will coordinate with the U.S. Geological Survey (USGS) to perform geophysical logging activities. As a contingency measure, EA will use a subcontract with a geophysical logging firm to support the investigation in the case where the USGS is unavailable.

EA will survey the locations and top-of-casing (TOC) elevations for those existing wells undergoing geophysical logging using portable GPS equipment. Elevations for each well TOC will be measured and referenced to a relative benchmark. As an alternative, EA may subcontract a local State of Texas-Registered Professional Licensed Surveyor to perform survey activities.

2.3 NEW MONITORING WELL INSTALLATION

EA will install new monitoring wells at up to 12 locations to provide additional information regarding the horizontal and vertical distribution of chromium in ground water at the Site. Monitoring wells will be constructed using a combination of multiple (nested) completions at each location, based on interpretation of geophysical logs from nearby wells and/or open boreholes.

The wells will be drilled in the approximate locations indicated on Figure A-3. Locations may be revised in the field upon consultation with, and approval from, EPA. Proposed well locations are as follows:

- Install up to eight nested monitoring wells addressing shallow Ogallala water-bearing zones (WBZs) north and south of U.S. Interstate Highway 20 (I-20) as follows:
 - Two 2-inch-diameter wells within a single borehole
 - Both wells in each nested pair should be screened within the Ogallala Formation (shallow aquifer) at two different depth intervals.
 - Five locations (well pairs) north of I-20
 - Three locations (well pairs) south of I-20 and focused more to the west (i.e., immediately south of the new monitoring wells north of I-20).
- Install up to four nested monitoring wells addressing both shallow (Ogallala Formation) and deep (Edwards-Trinity Aquifer) WBZs along WCR 120 (leading edge of plume) as follows:

- Drill two boreholes in close proximity, with two nested wells within each borehole.
- One borehole will include two 2-inch-diameter wells, each screened at two different depth intervals within the Ogallala Formation (shallow aquifer).
- Second borehole will include two 2-inch-diameter wells, each screened at two different depth intervals within the Trinity-Edwards Aquifer (deep aquifer).

With the exception of the wells to be constructed in the suspected source areas, the deeper borehole will be drilled first. The borehole will be geophysically logged to establish the screen intervals for all nearby wells. Within suspected source areas, the shallower borehole will be drilled and geophysically logged first to avoid cross contamination of the underlying aquifer.

2.4 MONITORING WELL GROUND WATER SAMPLING

Following well development, ground water samples will be collected from the newly-installed monitoring wells using snap samplers or low-flow sampling methodology. The number of snap samplers deployed along screened intervals will be determined following geophysical logging of the existing and new wells. The snap samplers will remain in the wells long enough for the well water, contaminant distribution, and flow dynamics to re-stabilize following sampler deployment. Ground water samples will be analyzed for TAL metals and hexavalent chromium. EA will coordinate with EPA prior to each mobilization to identify which wells are to be sampled and to ensure that the necessary access agreements are in place.

EA will survey the locations and TOC elevations for all newly-installed monitoring wells using portable GPS equipment. As an alternative, EA may subcontract a local State of Texas-Registered Professional Licensed Surveyor to perform survey activities.

2.5 GROUND WATER DATA COLLECTION

EA will install data-logger probes with a pressure transducer and temperature sensor in existing wells to collect continuous water monitoring data, contingent on the provision of access agreements. Probes will also be installed in new monitoring wells as they are constructed and added to the monitoring program, in consultation with EPA. Data will be used to develop ground water potentiometric maps for the respective water-bearing zones. Pumping data from local water wells and local rainfall data may also be collected as available.

3. PROPOSED PHASE 1 FIELD SCHEDULE

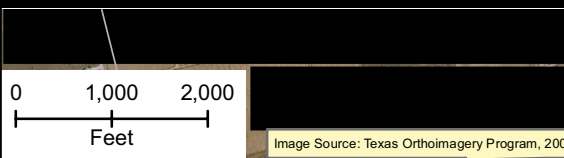
The following schedule will be followed for Phase 1 RI sampling activities. Field changes to schedule may be required due to adverse weather conditions or site access issues. EPA will be notified of conditions which may impact the field work schedule.

<u>Phase 1 RI Task</u>	<u>Schedule</u>
Utility location	15-24 November 2010
Tap water sampling	29 November – 3 December 2010

Geophysical logging of existing wells	15 November – mid-December 2010
Install and develop new monitoring wells	Early to mid-December 2010
Geophysical logging of new wells	Early to mid-December 2010
Collect ground water samples from new wells	10-15 January 2011
Install transducers	10-15 January 2011.

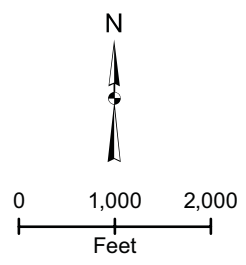
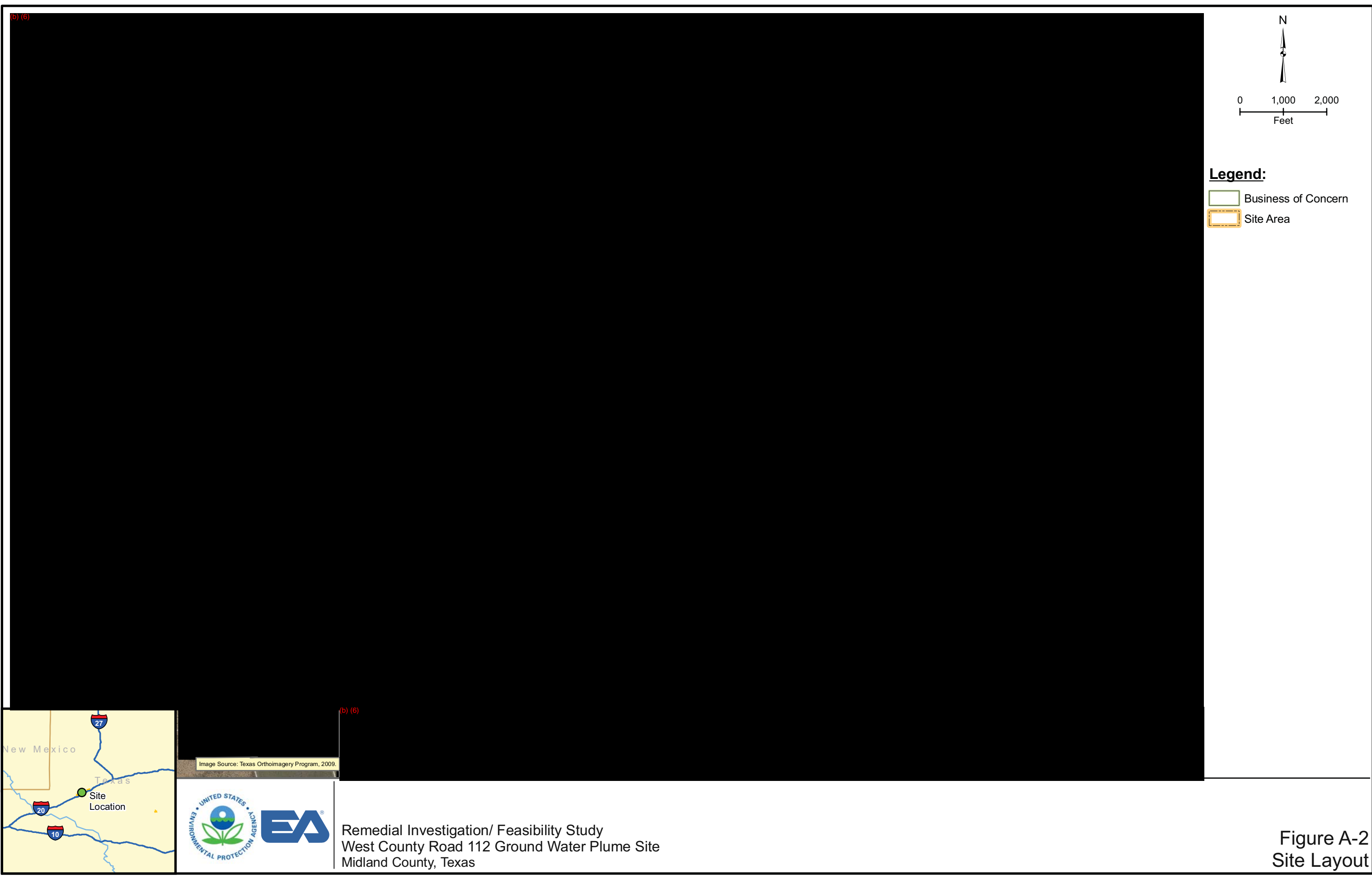
Figures

(b) (6)



Remedial Investigation/ Feasibility Study
West County Road 112
Ground Water Plume Site
Midland County, Texas

Figure A-1
Site Location



- Legend:**
- Business of Concern
 - Site Area



Image Source: Texas Orthoimagery Program, 2009.



Remedial Investigation/ Feasibility Study
West County Road 112 Ground Water Plume Site
Midland County, Texas

Figure A-2
Site Layout



Appendix B

Conceptual Site Model



Conceptual Site Model

Remedial Investigation/Feasibility Study West County Road 112 Ground Water Plume Site Midland, Midland County, Texas

Remedial Action Contract 2 Full Service Contract: EP-W-006-004 Task Order: 0065-RICO-A6R6

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LIST OF ACRONYMS AND ABBREVIATIONS

B&W	B&W Welding
COPC	contaminant of potential concern
CSM	Conceptual Site Model
EA	EA Engineering, Science, and Technology, Inc.
EPA	U.S. Environmental Protection Agency
ESI	Expanded Site Inspection
I-20	U.S. Interstate Highway 20
MCL	Maximum Contaminant Level
µg/L	microgram(s) per liter
POU	point-of-use
RI	Remedial Investigation
RSL	Regional Screening Level
Schlumberger	Schlumberger Technology Corporation
SI	Site Investigation
SSDAP	Superfund Site and Discovery and Assessment Program
TCEQ	Texas Commission on Environmental Quality
VOC	volatile organic compound
WBZ	water-bearing zone
WCR	West County Road

1. INTRODUCTION

This document presents the preliminary Conceptual Site Model (CSM) that was prepared by EA Engineering, Science, and Technology, Inc. (EA) for the West County Road (WCR) 112 Ground Water Plume Site (Site) located in Midland, Midland County, Texas. EA prepared the CSM for the U.S. Environmental Protection Agency (EPA) Region 6 as part of Task Order No. 0065-RICO-A6R6 under EPA Contract EP-W-006-004, in accordance with EPA Statement of Work, dated 26 July 2010 (EPA 2010c); and the EPA-approved EA Work Plan (Revision 01) dated 24 August 2010 (EA 2010).

Much of the information used in this CSM was obtained from the Texas Commission on Environmental Quality (TCEQ) Site Inspection (SI) Report (TCEQ 2010a) and the TCEQ Expanded Site Inspection (ESI) Report (TCEQ 2010b). Ground water data collected from private wells during TCEQ ground water sampling events (i.e., April 2009, May 2009, July 2009, January 2010, and February 2010) comprise the data set for this CSM. Additional information is referenced, as appropriate, in the following sections.

- Section 2—Background
- Section 3—Geology and Hydrogeology
- Section 4—Site Investigation Summary
- Section 5—Nature and Extent of Contamination
- Section 6—Risk Assessment
- Section 7—Potential Data Gaps and Recommendations
- Section 8—References.

Supporting tables and figures follow the text.

1.1 PURPOSE

The purpose of the CSM is to summarize existing data and assess its completeness, which will help determine potential data gaps that will direct future investigation activities. The following questions were addressed:

- Have the source(s) of contamination been identified?
- Have the nature and extent of soil and ground water impacts been delineated?
- What are the likely pathways for contaminant migration?
- Are there potentially complete ecological and human health exposure pathways?

1.2 SCOPE

The scope of the CSM included the following:

- Review existing reports, which detailed site characterization activities.
- Evaluate the site geology and hydrogeology.

- Compile the data sets into a single cogent presentation.
- Detail a CSM that describes the nature and extent of contamination and identifies potentially complete exposure pathways.
- Determine potential data gaps that will direct future investigation activities.

The main investigation component conducted to support investigation activities at the Site included collection of ground water samples from private water supply wells and upgradient and downgradient ground water monitoring wells. Soil samples were also collected from potential source areas identified during the TCEQ's ESI activities.

2. BACKGROUND

This section presents a description and background information for the Site.

2.1 SITE DESCRIPTION

The Site is a ground water plume of chromium, from an unknown source or sources, underlying an area located 2 blocks south of U.S. Interstate Highway 20 (I-20) in the southwest quadrant of the I-20 and Cotton Flat Road intersection. The Site is situated in Midland County, in and just south of the City of Midland, Texas (Figure B-1). The current ground water plume map identifies an area of approximately 260 acres and extending 1.25 miles from the center of the Site. The plume is centered in a mixed residential, commercial, and agricultural area. A site layout map is provided as Figure B-2.

The local ground water aquifers include the Ogallala and Edwards-Trinity Aquifers. The water supply north of I-20 is provided by the City of Midland. The city's water supply is Lake Ivie, located 50 miles north of Midland. South of I-20, ground water is the sole source of potable water, with private wells screened from 60 to 100 feet below ground surface (bgs), placing them within the Edwards-Trinity Aquifer system (TCEQ 2010b).

2.2 SITE BACKGROUND

Initial ground water impacts were reported to the TCEQ when a resident complained of yellow-tinted water to the TCEQ Region 7 office. The regional office collected ground water samples from a domestic well at 2604 WCR 112 on 8 April 2009. The concentrations of hexavalent chromium in these samples exceeded the EPA National Primary Drinking Water Regulation Maximum Contaminant Level (MCL) of 100 micrograms per liter ($\mu\text{g/L}$) for chromium.

On 20 and 29 April 2009, the TCEQ Region 7 office and TCEQ Superfund Site and Discovery and Assessment Program (SSDAP) personnel collected 14 additional ground water samples from water wells surrounding 2604 WCR 112. On 4 May 2009, SSDAP personnel continued collecting ground water samples from domestic wells within a 0.5-mile radius from the well located at 2604 WCR 112. By 4 November 2009, SSDAP personnel collected ground water samples from 234 drinking water wells within a 0.5-mile radius of the Site.

In July 2009, TCEQ conducted an SI, during which existing residential supply wells were sampled. A total of 30 samples were collected, including field duplicates. The SI also included collection and analysis of four soil samples from the Site and from the surrounding residential areas. None of the soil samples collected met the Hazard Ranking System observed release criteria. Ground water samples from 25 locations met the Hazard Ranking System observed release criteria for chromium. For the samples meeting the observed release criteria, all but one sample exceeded the MCL of 100 µg/L (EPA 2010a). Further information regarding the identification of a potential residual soil source area at the Site is a potential data gap that may be resolved by future investigatory activities.

Due to the presence of chromium concentrations greater than the MCL in the ground water, TCEQ initiated installation of anion-exchange point-of-use (POU) filtration systems. Based on the data collected through 4 November 2009, 45 private water supply wells have been impacted with chromium concentrations above the MCL of 100 µg/L. Anion exchange POU filtration systems have been installed at these wells, because the wells were determined to be a primary source of drinking water for the residences.

Subsequent ground water and soil sampling efforts (TCEQ 2010a, 2010b) were completed to identify potential source areas in soil and the extent of ground water impacts. Soil samples collected upgradient of the Site indicated that native soils were not a source of chromium. Ground water samples were collected upgradient and downgradient of three suspected source areas located north of I-20: Schlumberger Technology Corporation (Schlumberger), B&W Welding (B&W) facility, and the Williamson Gravel Pit. Ground water analysis identified impacts north of I-20 in both the Ogallala and Edwards-Trinity Aquifers, but at concentrations less than the MCL. TCEQ indicated that the potential source of the impacted ground water is an area southeast of the B&W facility between the facility and the center of the Site (2604 WCR 112). The TCEQ site inspections identified chromium concentrations in ground water in excess of the MCL in more than 40 residential wells. TCEQ designated the Site as a ground water plume without a known source.

Discrete sampling and the detailed evaluation of site area wells has provided an estimate of the downgradient distribution of aquifer contamination (TCEQ 2010a). However, the source area(s) for impacts from chromium has not been identified. This information will be used as a baseline to develop a strategy to evaluate potential future plume dynamics (e.g., migration, attenuation, etc.).

3. GEOLOGY AND HYDROGEOLOGY

This section contains a description of the geology and hydrogeology in the vicinity of the Site. Due to the similar nature of Ogallala and Edwards-Trinity sediments in places, the Site geology and hydrogeology will be updated during subsequent phases of the project as detailed geologic and geophysical logging data becomes available. Information presented in this section was obtained from the TCEQ SI and ESI reports (TCEQ 2010a, 2010b), unless otherwise noted below.

3.1 GEOLOGY

The uppermost geologic units beneath the Site consist of alluvium, the Ogallala Formation, and the Trinity Formation. Each of these is discussed below. In addition, a summary of the lithologic and hydrologic properties of the hydrogeologic subdivisions of the Ogallala and Edwards-Trinity aquifer system is presented in Table 1.

3.1.1 Alluvium

The alluvium is mostly composed of unconsolidated or poorly cemented clay, sand, gravel, and caliche. This alluvium aquifer overlies, and in some places is hydraulically connected to, underlying aquifers. At the Site, the alluvium ranges in thickness from approximately 2 to 10 feet.

3.1.2 Ogallala Formation

The Ogallala is composed primarily of sand, gravel, clay, and silt and generally has a saturated thickness of less than 100 feet in the Edwards Plateau area. The Ogallala consists of red and yellow clay, silt, fine to coarse gray and buff-colored sand, gravel, and caliche. The caliche ranges in thickness from 12 to 35 feet, varies from crumbly to very hard, and can be relatively impermeable in areas where it is massive and hard, and quite permeable in areas where it is extensively fractured.

3.1.3 Trinity Formation

The Trinity Aquifer consists of white to purple, loosely-consolidated, fine- to coarse-grained, well-sorted, unfossiliferous, quartz sandstone containing scattered lenses of quartz gravel. The sandstone can be cemented by silica. Lenses of red clay are scattered throughout, and a coarse conglomerate from about 5 to 10 feet thick, consisting of red and black pebbles of chert and other quartz varieties, generally occur at the base of the sandstone. In the Midland area, the Trinity Aquifer consists of medium- to coarse-grained, rounded white sand; locally ferruginous; weathering to a rust color; and containing white, black, and red pebbles scattered throughout.

3.1.4 Dockam Formation

Underlying the Trinity Aquifer is the Tertiary Dockham Formation, locally referred to as the “Red Beds”, a series of stiff, moderate to highly plastic clays with interbedded sandstone layers that occur to great depths.

3.2 HYDROGEOLOGY

Although both the Ogallala and Trinity Formations have been called out below the Site, the differentiation of these two units is difficult especially in those areas where soil descriptions are based on cuttings samples collected during well installation. Given the similar hydraulic properties of these two units, precise lithologic delineation of these units is not critical. Until more detailed data is obtained, those sands below the caliche and above the false red beds will be termed the undifferentiated Ogallala/Trinity formations.

As part of the ESI, the Shaw Group installed a total of five shallow monitoring wells for the TCEQ. Depths of these wells ranged between 35 and 79 feet bgs. A map of these and other existing monitoring wells is provided as Figure B-3. Based on these shallow wells, it appears that first water-bearing zone (WBZ) at the Site is encountered in the undifferentiated Ogallala/Trinity formations at a depth of approximately 22 feet bgs. A tan siltstone identified in MW-5 at a depth of 55 feet bgs may in fact be the false red beds that are identified at similar depths throughout the Midland-Odessa Area.

A second WBZ beneath this siltstone is certainly within the Trinity Formation. These sands extend to a depth of approximately 95 feet bgs where the true Red Beds are encountered. A majority of the private wells are screened between the “false” and “true” red beds with screens typically extending from 60 to 100 feet bgs.

Well depths from private and municipal water wells near the Site are approximately between 180 and 500 feet bgs.

4. SITE INVESTIGATION SUMMARY

Ground water data collected from private and municipal wells and monitoring wells during the TCEQ ground water sampling events (July 2009, January 2010, and February 2010) comprise the data set for this CSM. A summary of these investigations is provided in the following sections.

4.1 GROUND WATER INVESTIGATION SUMMARY

The ESI was completed in an attempt to identify potential sources upgradient of the Site. The ESI focused on three locations: Schlumberger, B&W, and the Williamson Gravel Pit (TCEQ 2010b). Ground water samples were collected from existing private water supply wells and newly-installed monitoring wells and analyzed for volatile organic compounds (VOCs) and metals. Total chromium was identified at low-level concentrations, the majority of which were below the MCL.

Ground water data collected from private/municipal wells and monitoring wells during two TCEQ ground water sampling events were utilized to evaluate the nature and extent of contamination in ground water at the Site. Table 2 summarizes ground water sample descriptions, while Table 3 presents monitoring well information.

Chromium was detected at concentrations greater than the MCL of 100 µg/L for total chromium in 25 private water supply wells in July 2009 (Table 4), in 20 of 63 sampling locations in January 2010 (Table 5), and 6 of 23 monitoring wells in February 2010 (Table 6). Because ground water flows from northwest to southeast, the chromium source area is likely upgradient (northwest) of the Site. Though concentrations of chromium were detected in ground water upgradient of the Site, the concentrations did not indicate that the source areas had been identified. Though chromium has been identified in both the Ogallala and Edwards-Trinity Aquifers, TCEQ was unable to identify any sources of chromium in a ground water investigation of three potential

source area sites northwest of the Site (TCEQ 2010b). As stated earlier, the transition from the overlying Ogallala Aquifer to the Edwards-Trinity in some locations is indistinguishable; hence, hydraulic connections between the two formations are common allowing for the vertical migration of impacts from the shallow aquifer to the deep, particularly in areas of strong downward head gradients in response to numerous pumping stresses in the area.

Figures B-4, B-5, and B-6 present the distribution of chromium in ground water samples collected in July 2009, January 2010, and February 2010, respectively. Note that the figures also include the 50 µg/L concentration contour to reflect the more conservative standard being proposed as the MCL for chromium.

The following general observations were made:

- The source(s) of chromium impacts to ground water has not been identified.
- The existing network of monitoring and private water wells is inadequate to identify the source area.
- The downgradient extent of contamination is not well defined in the undifferentiated Ogallala/Trinity aquifer.

Tables 4, 5, and 6 summarize the metals that were detected in ground water during the July 2009, January 2010, and February 2010 sampling events, and that are used in development of this CSM. The maximum concentration for each chemical analyte was compared to screening levels for the nature and extent discussion. The screening levels used in this CSM were National Primary Drinking Water Regulation MCLs (EPA 2010a) and EPA Regional Screening Levels (RSLs) for tap water (EPA 2010b).

4.1.1 Metals

Though chromium is the primary contaminant of potential concern (COPC), other metals also met the observed release criteria for the Site (TCEQ 2010a), including copper, lead, and manganese. Total chromium and hexavalent chromium were detected frequently at the Site (Tables 4, 5, and 6). Maximum chromium (total and hexavalent) concentrations exceeded the EPA MCL (EPA 2010a) for total chromium in ground water (100 µg/L) and EPA RSL (EPA 2010b) for hexavalent chromium in tap water (0.043 µg/L). No sources of chromium were detected at the Site or upgradient of the Site during the ESI completed by TCEQ. However, chromium is considered the primary COPC for the Site.

4.1.2 Volatile Organic Compounds

Although VOCs are being investigated upgradient of the Site, no potential sources of VOCs were identified at the Site during the initial SI completed by TCEQ. Therefore, VOCs are not considered primary COPCs.

4.2 SOIL SOURCE AREA INVESTIGATION

A total of five soil samples were collected during the SI completed by TCEQ (July 2009), including two samples to assess potential sources and two background soil samples. The analytical results indicated that concentrations of chromium did not meet the standards identified for the sampling event. Eight soil samples were collected by TCEQ during the ESI (February 2010) to try and identify potential source areas in soil in the vicinity of a residence at 2604 WCR 112. A ground-penetrating radar survey conducted in this area in February 2010 identified potential anomalies in this area. Soil samples collected at the anomalies did not identify sources of chromium contamination.

5. NATURE AND EXTENT OF CONTAMINATION

Chromium is considered a significant source of ground water contamination because concentrations exceed MCLs and RSLs. Although several soil samples have been collected in an attempt to identify source areas and background concentrations of chromium, the extent of impacts or sources has not been determined based on available analytical data.

5.1 CHROMIUM CHARACTERISTICS

The primary COPC for the Site is chromium (total and hexavalent). Chromium is an industrial metal used in many products and processes including chromate pigments in dyes, paints, inks, and plastics; chromates added as anticorrosive agents to paints, primers, and other surface coatings; and chromic acid electroplated onto metal parts to provide a decorative or protective coating. Hexavalent chromium can also be formed when performing “hot work,” such as welding on stainless steel or melting chromium metal. In these situations the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that converts the chromium to a hexavalent state. Chromium has been released to the environment through leakage and through poor storage/improper disposal practices. In nature, chromium is found in two oxidation states; trivalent and hexavalent. Hexavalent chromium is relatively mobile and acutely toxic. Trivalent chromium is immobile under moderately alkaline to slightly acidic conditions and has relatively low toxicity (EPA 1994).

Hexavalent chromium can be reduced and immobilized in the subsurface to the less toxic trivalent chromium with the presence of naturally-occurring reductants (EPA 1994). The potential reductants of hexavalent chromium include aqueous species, adsorbed ions, mineral constituents, and organic matter. EPA postulates that mixing of reductants and the hexavalent chromium plume should occur primarily through interactions of the plume with the soil matrix. These interactions include deposition of reductants such as iron (II) from mineral surfaces, direct and indirect surface reduction-oxidation reactions between hexavalent chromium, and the mineral surfaces and reduction by soil organic matter. As such, the reduction capacity of the aquifer should be evaluated to determine the potential for natural reduction of hexavalent chromium to the trivalent chromium form (e.g., identify natural reductants, determine if the amount of hexavalent chromium present is not greater than aquifer’s ability to reduce it, and determine if the rate of reduction is greater than the rate of transport, determine if trivalent

chromium remains mobile, and there is no oxidation of trivalent chromium to hexavalent chromium).

Following are the physical, chemical, and biological properties of hexavalent chromium that make ground water contamination from this metal problematic. These properties are as follows:

- **Volatilization:** This is not applicable to chromium.
- **Solubility:** The solubility of chromium compounds varies, depending primarily on the oxidation state. Trivalent chromium compounds, with the exception of acetate, hexahydrate of chloride, and nitrate salts, are generally insoluble in water (ATSDR 2010). The zinc and lead salts of chromic acid are practically insoluble in cold water. The alkaline metal salts (e.g., calcium, strontium) of chromic acid are less soluble in water. Some hexavalent compounds, such as hexavalent chromium oxide (or chromic acid), and the ammonium and alkali metal salts (e.g., sodium and potassium) of chromic acid, are readily soluble in water. The hexavalent chromium compounds are reduced to the trivalent form in the presence of organic matter or high reduction-oxidation conditions. However, in natural waters where there is a low concentration of reducing materials, hexavalent chromium compounds are more stable (EPA 1994).
- **Partitioning to Soil Materials:** Dissolved chromium in either valence state does not partition in soil, so significant retardation does not occur.

5.2 CONTAMINANT MIGRATION

The sources of chromium at the Site are unknown. After the release of chromium into the subsurface, movement of soluble hexavalent chromium through the subsurface continued to a point southeast of WCR 112. In this area, the downgradient boundary of the plume has not been identified. It is unknown if a continuing source of chromium (e.g., a tank, drums, etc.) are present.

The majority of the contamination in the saturated zone appears to be within the undifferentiated Ogallala/Trinity formations at depths of less than 60 feet as suggested by the high hexavalent chromium concentrations in the wells recently installed by Shaw (TCEQ 2010a). The lateral extent of contamination within this WBZ has yet to be determined.

Contamination within the actual Trinity Formation below the false red beds has occurred as a result of (1) migration down the well annulus of private wells that are screened to depths of approximately 100 feet bgs, (2) downward seepage in response to strong vertical hydraulic gradients in response to numerous pumping wells in areas absent the false red bed, where the Ogallala and Trinity Aquifers are in direct hydraulic communication. The extent of contamination in the Trinity Aquifer is also unknown.

6. RISK ASSESSMENT

This section presents a discussion of the human health and ecological CSMs for the Site.

6.1 HUMAN HEALTH CONCEPTUAL SITE MODEL

This section presents the human health CSM and summarizes information on sources of site chemicals, affected environmental media, chemical release and transport mechanisms, potentially exposed receptors, and potentially complete exposure pathways for each receptor. Figure B-7 presents the CSM for the Site.

6.1.1 Sources of Site Chemicals

Section 5 summarized the current understanding of the nature and extent of contamination at the Site. As shown in Figure B-7, sources for chemical exposure may include surface soil, subsurface soil, and ground water. A source area has not been identified; therefore, this CSM identifies potentially complete pathways that will only be complete if the source area is identified (i.e., assumes the source areas still exists). Further information regarding the identification of the source area at the Site is a potential data gap that will be filled by future investigatory activities.

6.1.2 Affected Environmental Media

Unknown source area(s) have resulted in chemical releases to soil (presumably somewhere in the vadose zone) and ground water at the Site. Further information regarding chemical releases at the Site is a potential data gap that will be filled by future investigatory activities.

6.1.3 Chemical Releases and Transport Mechanisms

Figure B-7 summarizes the chemical release and transport mechanisms for chromium at the Site. Based on these mechanisms, migration of chromium from the source area will be by infiltration to ground water and migration of ground water, which is used for domestic use.

6.1.4 Potentially Exposed Receptors

The Site is in a suburban environment with mixed residential, commercial, and industrial land use, so individuals frequenting these types of sites (e.g. residents, workers, trespassers, etc.) are the most likely potentially exposure scenarios at the Site. It is likely that construction or maintenance activities may occur at the Site that would require excavation, construction, or regrading; therefore, a construction worker scenario was considered. Finally, a trespasser scenario was included in the event that a receptor intrudes onto an impacted property.

6.1.5 Potentially Complete Exposure Pathways

According to EPA guidance (1989), a complete exposure pathway consists of four elements:

- A source and mechanism of chemical release

- A retention or transport medium (or media in cases involving transfer of chemicals)
- A point of potential human contact with the contaminated medium (referred to as the “exposure point”)
- An exposure route (such as ingestion) at the exposure point.

If any of these elements are missing (except when the source itself is the exposure point), then the exposure pathway is considered incomplete. For example, if receptor contact with the source or transport medium does not occur, then the exposure pathway is considered incomplete and is not quantitatively evaluated for risk. Similarly, if human contact with an exposure medium is not possible, the exposure pathway is considered incomplete and is not evaluated.

The CSM for the Site (Figure B-7) summarizes information on sources of COPCs, affected environmental media, COPC release and transport mechanisms that may occur at the Site, potentially exposed receptors, and potential exposure pathways for each receptor. Potentially complete exposure pathways are designated by a “C” in the CSM. Incomplete exposure pathways are designated by an “I.” Because some of these pathways are based on hypothetical-future exposure, they are considered potentially complete, but may not actually be complete for all receptors in the future.

Exposure routes for each receptor associated with the potentially complete exposure pathways are described in the following sections for the following potential receptors:

- Commercial/industrial worker scenario
- Construction worker scenario
- Trespasser scenario
- Residential scenario.

Commercial/Industrial Worker Exposure

The following exposure pathways for soil are potentially complete for the industrial worker scenario, if a residual soil source area is identified.

- Incidental ingestion of surface soil
- Dermal contact with surface soil
- Inhalation of chemicals adsorbed to windblown surface soils released to outdoor air.

The following exposure pathways for ground water are potentially complete for the industrial worker scenario, if water is not municipally supplied and the ground water utilized is impacted.

- Ingestion of ground water
- Dermal contact with ground water.

Construction Worker Exposure

The following exposure pathways for soil are potentially complete for the construction worker scenario if a residual soil source area is identified.

- Incidental ingestion of surface and subsurface soil
- Dermal contact with surface and subsurface soil
- Inhalation of chemicals adsorbed to windblown surface and subsurface soils released to outdoor air.

Trespasser Exposure

The following exposure pathways for soil are potentially complete for the trespasser scenario, if a residual soil source area is identified.

- Incidental ingestion of surface soil
- Dermal contact with surface soil
- Inhalation of chemicals adsorbed to windblown surface soils released to outdoor air.

Residential Exposure

The following exposure pathways for soil are potentially complete for the residential scenario, if a residual soil source area is identified.

- Incidental ingestion of surface soil
- Dermal contact with surface soil
- Inhalation of chemicals adsorbed to windblown surface soils released to outdoor air.

The following exposure pathways for ground water are potentially complete for the residential scenario, if water is not municipally supplied and the ground water utilized is impacted.

- Ingestion of ground water
- Dermal contact with ground water.

Ingestion of Impacted Ground Water

The most likely potentially complete exposure pathway is ingestion of impacted ground water by receptors in residences, and industrial, and commercial areas.

Chromium

Chromium, particularly hexavalent chromium, has been identified in drinking water sources at the Site. The Site is located north of I-20 between South Midkiff Road and Cotton Flat Road and south of the I-20 corridor between South County Road 1200 and South County Road; this area is

zoned residential, commercial, or industrial. Therefore, it is likely that residents and commercial/industrial workers in the vicinity of the Site could be exposed to chromium from the soil or ground water.

6.2 ECOLOGICAL CONCEPTUAL SITE MODEL

The Site is a mixed environment with residential or commercial/industrial land use. Potential soil source areas have not been identified; therefore, an evaluation of potential ecological receptors was not conducted in this CSM. It is unlikely that ecological receptors will be exposed to ground water because the depth to ground water is greater than 4 feet bgs (i.e., the deepest depth of burrowing animals) and no ground water to surface water migration pathways have been identified. In the event that a potential soil source area or ground water to surface water migration pathway is identified during investigatory activities, an ecological CSM may be developed, as necessary. Further information regarding identification of a potential residual soil source area at the Site is a potential data gap that will be filled by future investigatory activities.

7. DATA GAPS AND RECOMMENDATIONS

Future sampling activities and a detailed evaluation of site area wells will assist in determining the dimensional distribution of aquifer contamination (i.e., extent of contamination) and resolve potential data gaps. This information will also be used to determine if the plume is spreading and potentially threatening other private and public drinking water wells.

7.1 DATA GAPS

A discontinuity of the historical water well information versus the sampling identification was observed during the development of this CSM. In many instances, station identification numbers (IDs) were used as opposed to Well IDs in referring to the analytical results. This data gap can be resolved with the development of a database key to identify a unique name for each well at each individual physical address. Additional information regarding the completion depth of the private wells would also be useful in assessing migration pathways.

Although actual source locations have not been delineated, three facilities in the immediate vicinity of the Site are all like contributors to the chromium plume. Before any remedies can be considered, the sources of contamination must be identified.

To date, the extent of ground water contamination has not been determined either vertically or horizontally. Conceptually, it appears that the majority of the chromium is within the undifferentiated Ogallala/Trinity formations; this needs to be verified. Additional data also needs to be collected to identify additional pathways to the deeper portions of the aquifer.

Although there is some indication of plume morphology based on the data collected from the existing wells, information regarding the direction of ground water flow in the different water bearing zones does not exist. This data gap can also be filled by the installation of additional monitoring wells.

7.2 RECOMMENDATIONS

Additional site characterization should be performed in a phased approach as follows:

Determination of Source Areas

Source delineation is likely to require additional soil sampling and coordination with those facilities that were known to use chromium in their day to day operations.

Vertical Profiling of Areas with High Concentrations

For this activity additional well pairs are proposed with short screen intervals. Water table wells should be completed to the top of the false red beds, and deeper wells screened between the base of the false red beds and to the top of the true red beds, at a depth of approximately 100 feet bgs. Given the current data set, four to six nested well pairs should be sufficient to delineate the plume vertically.

Horizontal Plume Delineation

Based on the results of the vertical plume delineation, additional ground water monitoring wells should be installed above the false red beds and between the false and true red beds.

Evaluation of Aquifer Parameters

Based on the results of the plume delineation activities, and evaluation of hydraulic parameters is recommended. A limited aquifer testing program will be useful in remedy selection.

Ground Water Monitoring Activities

At the same time that these activities are ongoing, sampling of the residential wells should continue, with the wells being sampled for total metals and hexavalent chromium. Once the plume morphology is better constrained, additional water quality data supporting monitored natural attenuation should also be collected.

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Tables

TABLE 1 AQUIFER SYSTEM HYDROGEOLOGY

System	Series	Group	Formation	Description of Rocks	Hydrogeologic Units
Quaternary	Pleistocene to Recent		Alluvium, eolian and lacustrine deposits	Sand, clay, silt, caliche, and gravel.	Generally yields small amounts of water to wells; may yield large amounts of water along stream valleys of Edwards Plateau.
Tertiary	Late Miocene to Pliocene	Washita	Ogallala	Tan, yellow, and reddish brown silt, clay, sand, and gravel. Caliche layers common near surface.	Yields moderate to large amounts of water to wells across Southern High Plains. Yields small to moderate amounts of water in Andrews, Martin, Howard, Ector, Midland, and Glasscock Counties.
Cretaceous	Comanche	Fredericksburg	Duck Creek	Yellow, sandy shale and thin gray to yellowish brown argillaceous limestone beds.	Yields small amounts of water locally to wells.
			Kiamichi	Gray to yellowish brown shale with thin interbeds of gray argillaceous limestone and yellow sandstone.	Yields small amounts of water locally to wells.
			Edwards	Light gray to yellowish gray, thick to massive bedded, fine-to coarse-grained limestone.	Generally yields fairly small amounts of water to wells beneath Southern High Plains, but may yield large amounts of water locally due to fractures and solution cavities.
			Comanche Peak	Light gray to yellowish brown, irregularly bedded argillaceous limestone with thin interbeds of light gray shale.	
			Walnut	Light gray to yellowish brown argillaceous sandstone; thin-bedded gray shale; light gray to grayish yellow argillaceous limestone.	Not known to yield water to wells.
		Trinity	Antlers	White, gray, yellowish brown to purple, argillaceous, loosely cemented sand, sandstone, and conglomerate with interbeds of siltstone and clay.	Yields small to moderate amounts of water to wells. Primary aquifer of Cretaceous system within the study area.
Triassic		Dockum	Chinle	Red, maroon to purple shale. Thin. discontinuous beds of sand and silt.	May yield small amounts of water to wells. Commonly known as the "red beds" that form the base of the High Plains aquifer.
			Santa Rosa	Multi-colored fine- to coarse-grained micaceous sandstone with some claystone and shale interbeds.	Yields moderate amounts of water to wells.
			Tecovas	Red to red-brown shale with fine-grained micaceous sand.	Not known to yield water to wells.

**TABLE 2 GROUND WATER SAMPLE DESCRIPTIONS FOR JULY 2009
AND FEBRUARY 2010 SAMPLING EVENTS**

Station ID	Sample Location	Rationale	Collection Date	Well Screen/Well Depth (bgs)
JULY 2009				
GW-01	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-02	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-03	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-04	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-05	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-06	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
GW-07	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-08	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA/80 feet
GW-09	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-10	Residential drinking water well (b) (6)	Background ground water sample	7/20/2009	NA/90 feet
GW-11	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA/80 feet
GW-12	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-13	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-14	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA
GW-15	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA/76 feet
GW-16	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/21/2009	NA
GW-17	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
GW-18	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
GW-19	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/80 feet
GW-20	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/87 feet
GW-21	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/62 feet
GW-22	Residential drinking water well (b) (6)	Background ground water sample	7/20/2009	NA

**TABLE 2 GROUND WATER SAMPLE DESCRIPTIONS FOR JULY 2009
AND FEBRUARY 2010 SAMPLING EVENTS**

Station ID	Sample Location	Rationale	Collection Date	Well Screen/Well Depth (bgs)
GW-25	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
GW-26	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
GW-27	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/92 feet
GW-28	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/70 feet
GW-29	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/65 feet
GW-31	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/63 feet
GW-33	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/20/2009	NA/80 feet
GW-34	Residential drinking water well (b) (6)	Assess release contaminants to ground water	7/22/2009	NA
FEBRUARY 2010				
GW-E	Monitoring well located at 4 South Industrial Loop (B&W MW)	Assess release contaminants to ground water at B&W	2/10/2010	NA
GW-01	Monitoring well located in the back yard of 2406 W CR 112; or adjacent property (TCEQ MW)	Assess release contaminants to ground water at the center of the site	2/09/10	30-37 feet/NA
GW-02	Monitoring well located in the front yard of 2406 W CR 112; or adjacent property (TCEQ MW)	Assess release contaminants to ground water at the center of the site	2/09/10	36-44 feet/NA
GW-03	Monitoring well located in the front yard of 2406 W CR 112; or adjacent property (TCEQ MW)	Assess release contaminants to ground water at the center of the site	2/09/10	31-40 feet/NA
GW-04	Monitoring well located north of 2605 W CR 110 (Schlumberger MW)	Assess release contaminants to ground water at the center of the site and B&W	2/09/10	30-36 feet/NA
GW-4L	Monitoring well located at 4 South Industrial Loop (B&W MW)	Assess release contaminants to ground water at B&W	2/10/10	15-35 feet/NA
GW-05	Monitoring well located north of 2605 W CR 110 (Schlumberger MW)	Assess release contaminants to ground water at the center of the site and B&W	2/09/10	48-53 feet/NA
GW-06	Monitoring well located north of 2605 W CR 110 (Schlumberger MW)	Assess release contaminants to ground water at the center of the site and B&W	2/09/10	72-75 feet/NA

**TABLE 2 GROUND WATER SAMPLE DESCRIPTIONS FOR JULY 2009
AND FEBRUARY 2010 SAMPLING EVENTS**

Station ID	Sample Location	Rationale	Collection Date	Well Screen/Well Depth (bgs)
GW-07	Monitoring well located at 3000 W I-20 (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	17-36 feet/NA
GW-08	Monitoring well located at 3000 W I-20 (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	16-36 feet/NA
GW-09	Monitoring well located at 3000 W I-20 (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	90-97 feet/NA
GW-10	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	35-36 feet/NA
GW-11	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	40-56 feet/NA
GW-12	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit (Schlumberger MW)	Assess release contaminants to ground water at Williamson Gravel Pit and B&W	2/08/10	57-70 feet/NA
GW-13	Monitoring well located at 3020 West Front Street (TCEQ MW)	Assess release contaminants to ground water at Schlumberger	2/09/10	13-35 feet/NA
GW-14	Monitoring well located at 3020 West Front Street (TCEQ MW)	Assess release contaminants to ground water at Schlumberger	2/09/10	39-79 feet/NA
GW-15	Monitoring well located at 4 South Industrial Loop (B&W MW)	Assess release contaminants to ground water at B&W	2/10/10	15-30 feet/NA
GW-20	Monitoring well located at 432 East Industrial Loop (Schlumberger MW)	Assess release contaminants to ground water at Schlumberger	2/08/10	40-50 feet/NA
GW-20a	Monitoring well located at 432 East Industrial Loop (Schlumberger MW)	Assess release contaminants to ground water at Schlumberger	2/08/10	56-70 feet/NA
GW-39	Monitoring well located at 2002 Cotton Flat Road	Assess release contaminants to ground water	2/10/10	NA
GW-41	Monitoring well located at 4 South Industrial Loop (B&W MW)	Assess release contaminants to ground water at B&W	2/10/10	25-40 feet/NA

**TABLE 2 GROUND WATER SAMPLE DESCRIPTIONS FOR JULY 2009
AND FEBRUARY 2010 SAMPLING EVENTS**

Station ID	Sample Location	Rationale	Collection Date	Well Screen/Well Depth (bgs)
Notes: bgs = below ground surface B&W = B&W Welding facility CR = County Road MW = monitoring well NA = not available Schlumberger = Schlumberger Technology Corporation TCEQ = Texas Commission on Environmental Quality I-20 = U.S. Interstate Highway 20				

TABLE 3 MONITORING WELL INFORMATION

Monitoring Well ID	Well Screen	Well Location	Well Owner
MW-01	30-37 feet bgs	Monitoring well located in the back yard of 2406 W CR 112; or adjacent property	TCEQ
MW-02	36-44 feet bgs	Monitoring well located in the front yard of 2406 W CR 112; or adjacent property	TCEQ
MW-03	31-40 feet bgs	Monitoring well located in the front yard of 2406 W CR 112; or adjacent property	TCEQ
MW-04 ¹	13-35 feet bgs	Monitoring well located at 3020 West Front Street	TCEQ
MW-05 ¹	39-79 feet bgs	Monitoring well located at 3020 West Front Street	TCEQ
MW-09	NA	Monitoring well located at (b) (6)	Unknown
MW-20A ¹	40-50 feet bgs	Monitoring well located at 432 East Industrial Loop	Schlumberger
MW-20B ¹	56-70 feet bgs	Monitoring well located at 432 East Industrial Loop	Schlumberger
MW-22 ¹	35-36 feet bgs	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit	Schlumberger
MW-22A ¹	40-56 feet bgs	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit	Schlumberger
MW-22B ¹	57-70 feet bgs	Monitoring well located at the southeast corner of S CR 1205 and Harris Ave at the Williamson Gravel Pit	Schlumberger
MW-23 ¹	17-36 feet bgs	Monitoring well located at 3000 W I-20	Schlumberger
MW-23A ¹	16-36 feet bgs	Monitoring well located at 3000 W I-20	Schlumberger
MW-23B ¹	90-97 feet bgs	Monitoring well located at 3000 W I-20	Schlumberger
MW-26 ¹	30-36 feet bgs	Monitoring well located north of 2605 W CR 110	Schlumberger
MW-26A ¹	48-53 feet bgs	Monitoring well located north of 2605 W CR 110	Schlumberger
MW-26B ¹	72-75 feet bgs	Monitoring well located north of 2605 W CR 110	Schlumberger
MW-E	NA	Monitoring well located at 4 South Industrial Loop	B&W
MW-101	18-33 feet bgs	Monitoring well located at 4 South Industrial Loop	B&W
MW-102	25-40 feet bgs	Monitoring well located at 4 South Industrial Loop	B&W

TABLE 3 MONITORING WELL INFORMATION

Monitoring Well ID	Well Screen	Well Location	Well Owner
MW-105	15-35 feet bgs	Monitoring well located at 4 South Industrial Loop	B&W
MW-202	15-30 feet bgs	Monitoring well located at 4 South Industrial Loop	B&W
MW-401	15-35 feet bgs	Monitoring well located at 4 South Industrial Loop	B&W

Notes:

¹ Denotes nested monitoring well

B&W = B&W Welding Facility

bgs = below ground surface

CR = County Road

MW = monitoring well

NA = not available

Schlumberger = Schlumberger Technology Corporation

TCEQ = Texas Commission on Environmental Quality

I-20 = U.S. Interstate Highway 20

Source: Texas Commission on Environmental Quality, Expanded Site Inspection Report, July 2010.

**TABLE 4 ANALYTICAL RESULTS FOR CHROMIUM IN GROUND WATER
JULY 2009 SAMPLING EVENT**

Sample ID	Results (µg/L)
GW-01	<i>431</i>
GW-02	<i>239</i>
GW-03	<i>2,510</i>
GW-04	<i>1,980</i>
GW-05	<i>217</i>
GW-06	<i>116</i>
GW-07	<i>110</i>
GW-08	<i>350</i>
GW-09	<i>375</i>
GW-11	<i>466</i>
GW-12	<i>191</i>
GW-13	<i>530</i>
GW-14	<i>4,450</i>
GW-15	<i>107</i>
GW-16	<i>440</i>
GW-17	<i>47</i>
GW-18	<i>313</i>
GW-19	<i>1,010</i>
GW-20	<i>497</i>
GW-21	<i>1,400</i>
GW-25	<i>1,140</i>
GW-27	<i>694</i>
GW-28	<i>1,040</i>
GW-29	<i>1,400</i>
GW-31	<i>3,780</i>
GW-34	<i>491</i>

Notes:

µg/L = microgram(s) per liter

MCL = Maximum Contaminant Level

Bold-italicized values indicate detections above the MCL of 100 µg/L for chromium

Source: Texas Commission on Environmental Quality, Site Inspection Report, February 2010.

**TABLE 5 ANALYTICAL RESULTS FOR CHROMIUM IN GROUND WATER
JANUARY 2010 SAMPLING EVENT**

Sample ID	Results (µg/L)
GW-05	44.4
GW-11A	881
GW-19A	208
GW-20A	464
GW-23A	898
GW-29	35.7
GW-36	32.8
GW-38	35.7
GW-42A	3,590
GW-43A	639
GW-44A	1,710
GW-45A	1,380
GW-46A	1,390
GW-47A	4,780
GW-48A	556
GW-49A	1,150
GW-50A	917
GW-53	ND
GW-54	ND
GW-55	19.2
GW-56	3.09
GW-57	31.9
GW-64A	106
GW-83	33.4
GW-90A	340
GW-98A	99.7
GW-104A	420
GW-105A	79.3
GW-106	6.96
GW-107	35.9
GW-126A	107
GW-129	ND
GW-151	68.9
GW-152	17.5
GW-166	ND
GW-183	ND
GW-184	ND
GW-191	ND
GW-192	40.2
GW-194	21.5
GW-196	23.4
GW-197	38.7

**TABLE 5 ANALYTICAL RESULTS FOR CHROMIUM IN GROUND WATER
JANUARY 2010 SAMPLING EVENT**

Sample ID	Results (µg/L)
GW-198	35.6
GW-254A	389
GW-255	ND
GW-256	2.12
GW-258	ND
GW-259A	28.8
GW-260A	622
GW-261A	240
GW-269	ND
GW-276	ND
GW-288	3.28
GW-291	ND
GW-294	ND
GW-299A	179
GW-338	ND
GW-345	ND
GW-359	ND
GW-383	ND
GW-384	ND
GW-504	ND
GW-550	ND
<p>Notes:</p> <p>µg/L = microgram(s) per liter</p> <p>MCL = Maximum Contaminant Level</p> <p>ND = not detected</p> <p><i>Bold-italicized</i> values indicate detections above the MCL of 100 µg/L for chromium</p> <p>Source: Texas Commission on Environmental Quality, Project Database.</p>	

**TABLE 6 ANALYTICAL RESULTS FOR CHROMIUM IN GROUND WATER
FEBRUARY 2010 SAMPLING EVENT**

Sample ID	Monitoring Well ID	Results (µg/L)
GW-01	MW-01	<i>3,770</i>
GW-02	MW-02	<i>4,900</i>
GW-03	MW-03	<i>3,620</i>
GW-04	MW-26	<i>1,220</i>
GW-05	MW-26A	<i>3,560</i>
GW-06	MW-26B	NA
GW-07	MW-23	22.9
GW-08	MW-23A	<i>120</i>
GW-09	MW-23B	NA
GW-10	MW-22	ND
GW-11	MW-22A	ND
GW-12	MW-22B	NA
GW-39	MW-09	NA
GW-41	MW-102	ND
GW-105	MW-105	ND
GW-4L	MW-401	24.3
GW-E	MW-E	82.6
GW-20	MW-20A	ND
GW-20A	MW-20B	58.8
GW-13	MW-04	ND
GW-14	MW-05	NA
GW-15	MW-202	51.4
GW-55	MW-101	ND

Notes:

µg/L = microgram(s) per liter

MCL = Maximum Contaminant Level

ND = not detected

Bold-italicized values indicate detections above the MCL of 100 µg/L for chromium

Source: Texas Commission on Environmental Quality, Expanded Site Inspection Report, July 2010.

Figures

(b) (6)



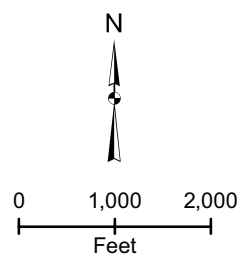
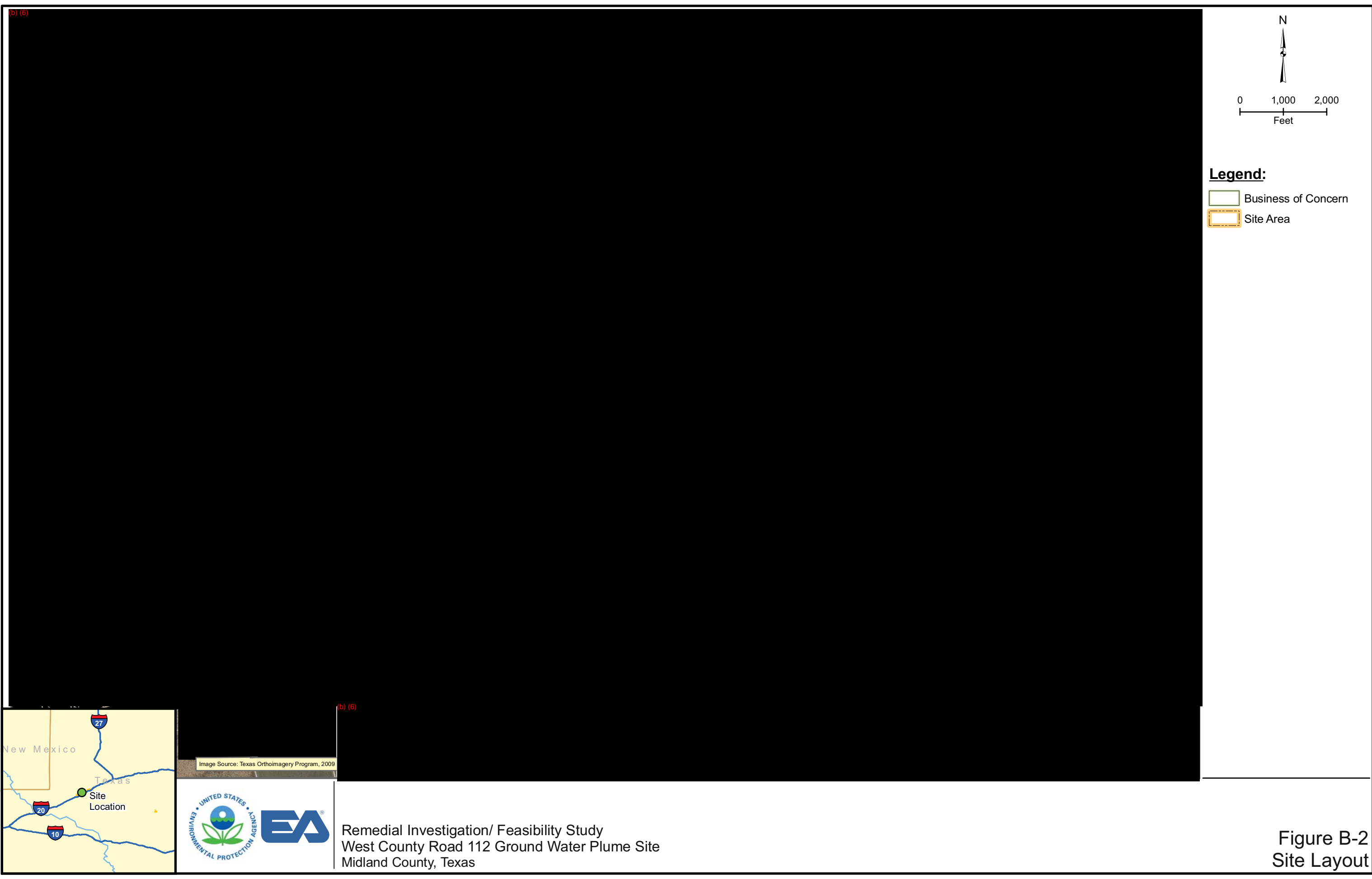
0 1,000 2,000
Feet

Image Source: Texas Orthoimagery Program, 2009.



Remedial Investigation/ Feasibility Study
West County Road 112
Ground Water Plume Site
Midland County, Texas

Figure B-1
Site Location



- Legend:**
- Business of Concern
 - Site Area

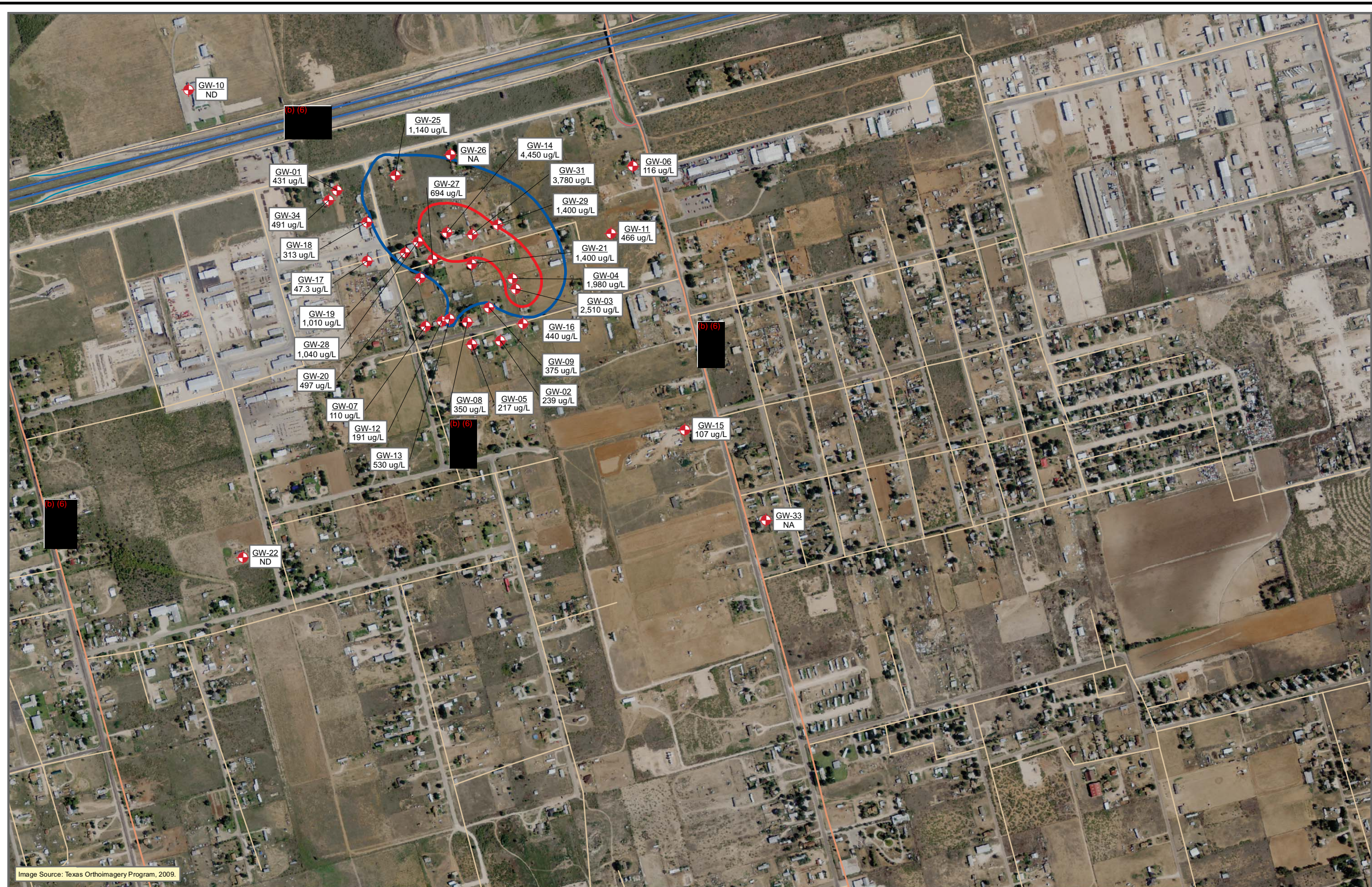


Image Source: Texas Orthoimagery Program, 2009



Remedial Investigation/ Feasibility Study
West County Road 112 Ground Water Plume Site
Midland County, Texas

Figure B-2
Site Layout



Legend:

Water Supply Wells

Concentration

500 ug/L

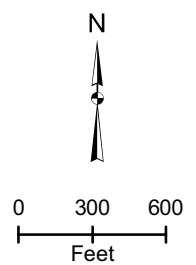
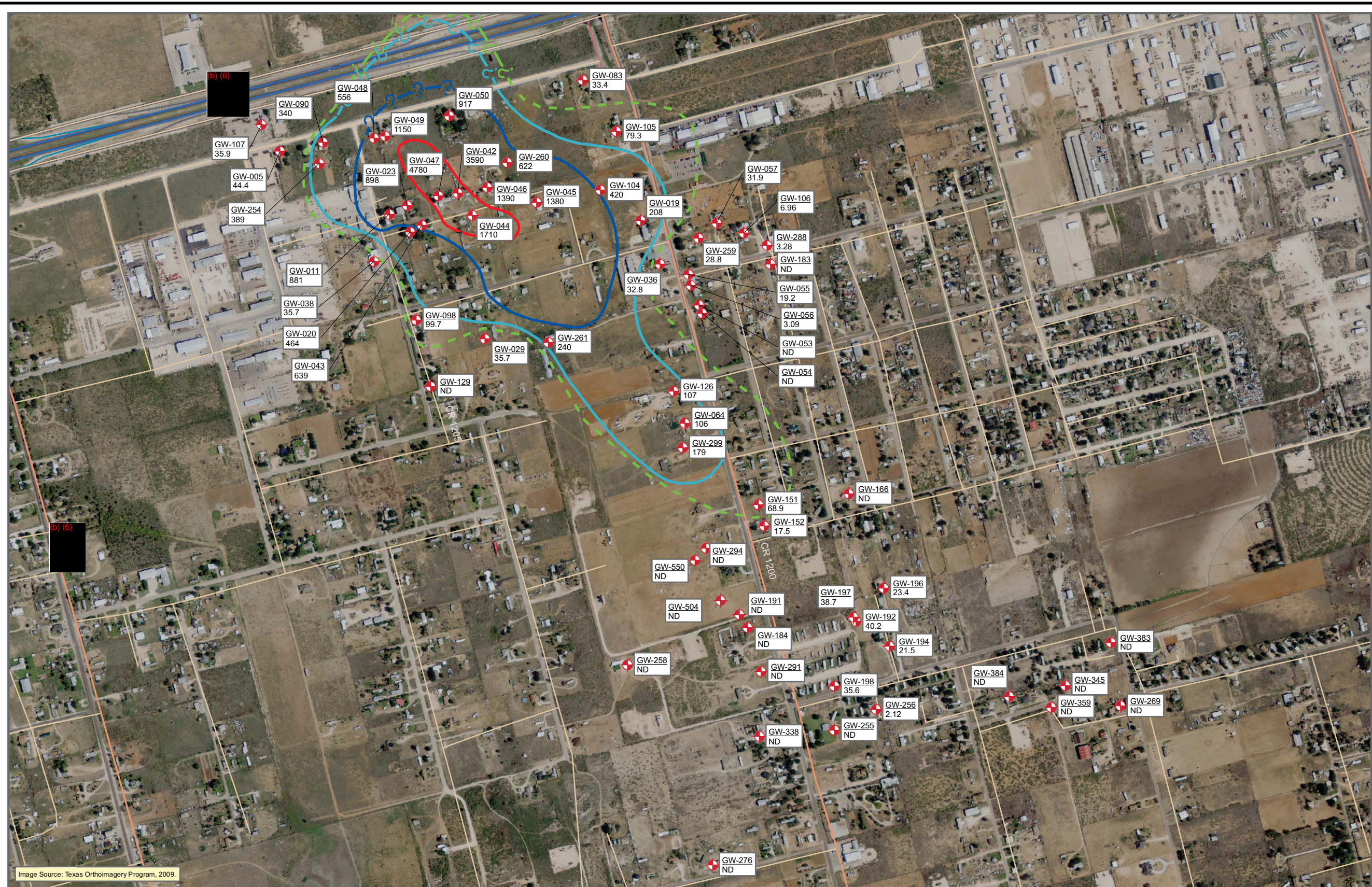
1,500 ug/L

Maximum Contaminant Level
for Total Chromium = 50 ug/L



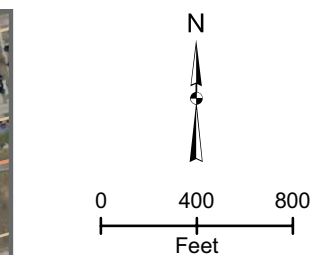
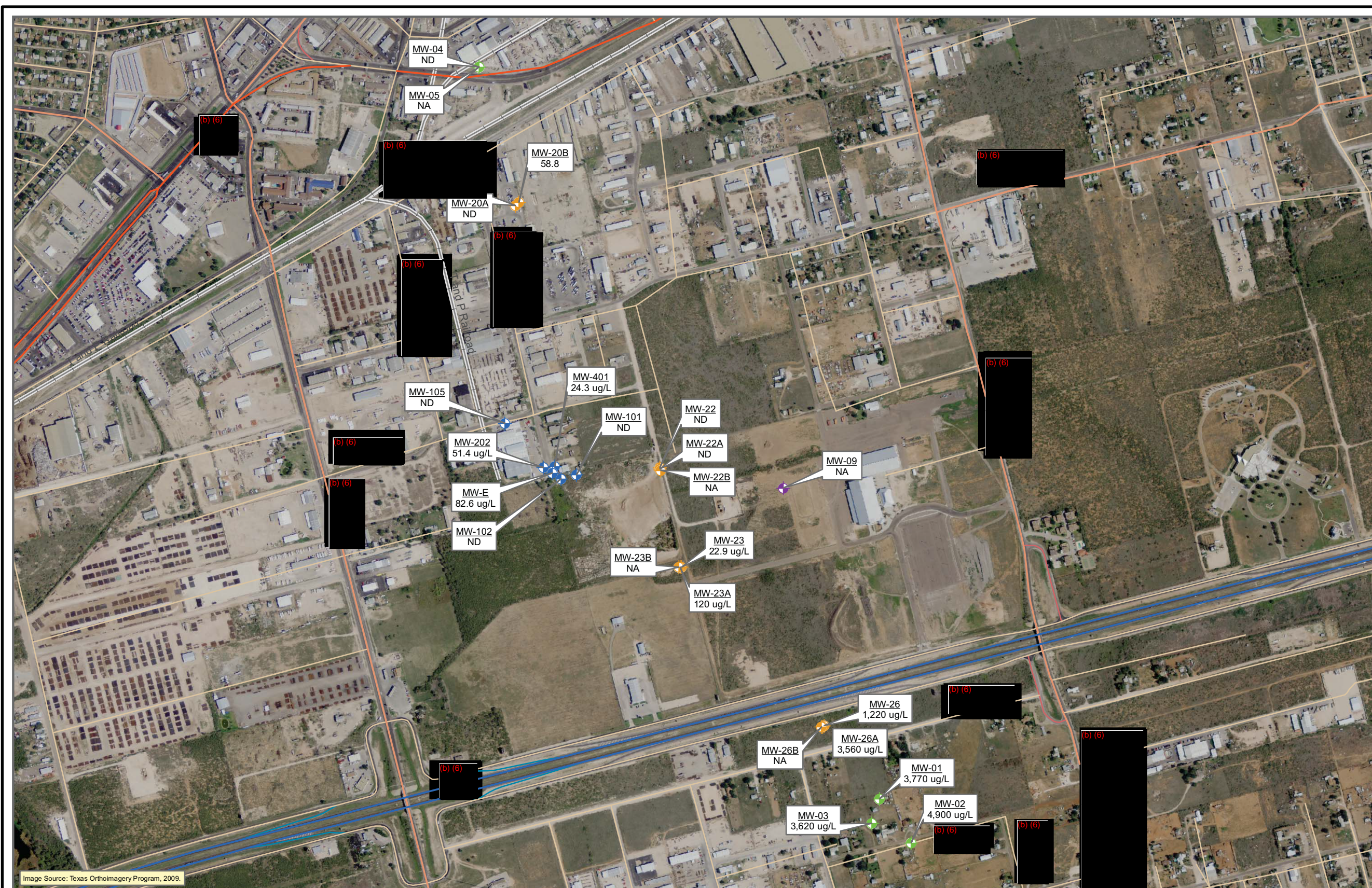
Remedial Investigation/ Feasibility Study
West County Road 112 Ground Water Plume Site
Midland County, Texas

Figure B-4
Concentrations of Total Chromium
in Ground Water (July 2009)



Remedial Investigation/ Feasibility Study
 West County Road 112 Ground Water Plume Site
 Midland County, Texas

Figure B-5
 Concentrations of Total Chromium
 in Ground Water (January 2010)



- Legend:**
- Monitoring Well Location**
Installed by:
- B&W Welding
 - Schlumberger
 - TCEQ
 - Unknown

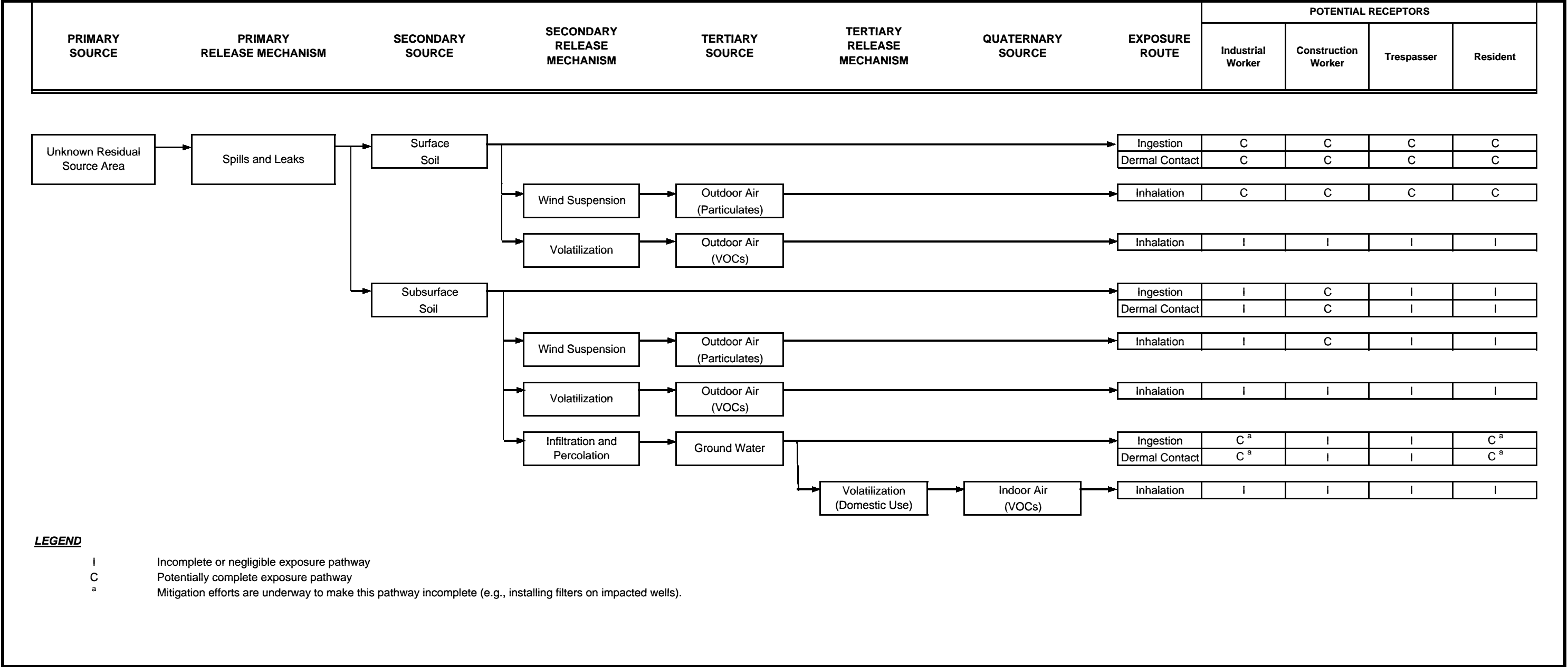


Remedial Investigation/ Feasibility Study
West County Road 112 Ground Water Plume Site
Midland County, Texas

Figure B-6
Concentrations of Total Chromium
in Monitoring Wells - February 2010

2010-10-27 T:\Federal\palrac\110055-west county road 112\gis\projects\leap_figures\figurexx_july2010_mw.mxd EA-Dallas jschwartz

FIGURE B-7
PRELIMINARY HUMAN HEALTH CONCEPTUAL SITE MODEL
WEST COUNTY ROAD 114 GROUND WATER PLUME SITE



Appendix C

Field Forms

DAILY FIELD ACTIVITIES SUMMARY REPORT			
PROJECT NAME: West County Road 112 Ground Water Plume Site RI/FS			
Date:	Shift Beginning:	hours	Shift Ending: hours
RAC II Contract No.: EP-W-06-004		Task Order No.: 0065-RICO-A6R6	
EPA Region 6 TOM: Vincent Malott		Project Manager: April Ballweg	
Site Manager:		Sample Manager:	
Project Geologist:		SHSO:	
Personnel on site	Name	Affiliation	Reason for being on site
EPA:			
EA:			
DBS&A:			
Subcontractors:			
Other:			
Work Performed			
Report prepared by (name and date)			

Tap Water Sampling Data Sheet
(for single-port sampling or pre-filter only)

Well ID: _____ Sample ID: _____ Sample Time: _____

Well owner/location/residence: _____

Street address: _____

Filtration system? (circle one) Y N

Sampling personnel: _____

Start purge time: _____

Weather: _____

End purge time: _____

Purge Rate (gal/min): _____

Sample collected at (circle as appropriate): Wellhead tap In-line House tap

Field Parameters:

Time:	_____	_____	_____	_____	Within	Circle One:
Specific Conductance:	_____	_____	_____	_____	10%	$\mu\text{S/cm}$ mS/cm
pH:	_____	_____	_____	_____	+/- 0.5	
Temperature:	_____	_____	_____	_____	+/- 1 C	$^{\circ}\text{F}$ $^{\circ}\text{C}$
ORP:	_____	_____	_____	_____	mV	

Notes/Comments: _____

Well Configuration

Recorded By: _____

Tap Water Sampling Data Sheet (for multi-port sampling and/or in-line filtration systems)

Well ID: _____ Sample ID: _____ Sample Time: _____

Well owner/location/residence: _____

Street address: _____

Filtration system? (circle one) Y N Sampling personnel: _____

Start purge time: _____ Weather: _____

End purge time: _____ Purge Rate (gal/min): _____

Sample collected at (circle as appropriate): Wellhead tap In-line House tap

Well ID GPS Coordinates: _____

If multiple samples collected (i.e., EPA/State filtration system in place), please complete the following:

Collection Point

Sample ID: _____ Sample Time: _____ Pre-filter (A)

Sample ID: _____ Sample Time: _____ In-line filter (B)

Sample ID: _____ Sample Time: _____ Post-filter (C)

Field Parameters:

Time:					Within	Circle One:
Specific Conductance:					10%	μs/cm ms/cm
pH:					+/- 0.5	
Temperature:					+/- 1 C	°F °C
ORP:						mV

Notes/Comments: _____

Well Configuration

Recorded By: _____

Well ID:		Sample ID:		Sample Time:	
----------	--	------------	--	--------------	--

[illegible]

Recorded By: _____

Snap Sampler Ground Water Sampling Data Sheet

Date: _____

Well ID: _____ Sample ID: _____ Sample Time: _____

Well owner/location/residence: _____

Street address: _____ Sampling personnel: _____

Weather: _____

SNAP SAMPLER DEPTH (feet)	SAMPLE TIME	NOTES/COMMENTS
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Field Parameters:

Time:	_____	_____	_____	_____	_____	
Specific Conductance:	_____	_____	_____	_____	_____	us/cm or ms/cm
pH:	_____	_____	_____	_____	_____	
Temperature:	_____	_____	_____	_____	_____	F° or C°
ORP:	_____	_____	_____	_____	_____	mV

Notes/Comments: _____

Recorded By: _____

MIDESSA GROUND WATER PLUME SITE

SOIL SAMPLE FIELD DATA SHEET

Site: West County Road 112 Ground Water Plume Site, Midland County, TX

Location: _____

Weather: _____

FIELD SAMPLING PERSONNEL: _____

SAMPLE ID: _____

SAMPLE DATE/TIME: _____

DEPTH (ft): _____

LOCATION MAP:This image shows a full page of blank graph paper. The grid consists of small, equal-sized squares formed by thin, dark gray lines. There are 20 columns and 20 rows of these squares, creating a total of 400 square units. The background is white, and the grid covers the entire area of the page without any margins or additional markings.**TOTAL NO. OF CONTAINERS:**

40 ml (unpreserved) _____

2 oz jar _____

4 oz jar _____

8 oz jar _____

Other _____

ANALYSIS:

VOC - Method 5035 _____

Moisture _____

Metals _____

Geotechnical _____

Other _____

FIELD/LAB QC SAMPLE:

MS/MSD	_____
Duplicate	_____
Field Blank	_____
ER	_____
Other	_____

SAMPLING METHOD:

Drilling _____
Slide hammer/auger _____
Scoop/trowel _____
Direct-push _____
Other _____

NOTES/COMMENTS:

**West County Road 112 Ground Water Plume Site
Utilities and Structures Checklist**

Area of Interest: _____

Prepared By: _____

Location: _____















Date: _____















One Call Checklist	Number	Date Called	Date Scheduled	Date Field Verified
One Call Number (State)				
Client				
City/County/Other				















Utilities & Structures Type	Present	Not Present	How Marked? ⁽¹⁾	Company	Name	Signature
Natural Gas Line						
Steam Line						
Water Line (public/private)						
Sewer Line (public/private)						
Storm Drain						
Telephone/Fiber Optic Lines (overhead/buried)						
Electric Power Lines (overhead/buried)						
AST/UST Product Tank/Lines						
Septic Tank/Drain Field						
Petroleum Products Lines						
Cable (TV)						
Switch/Signal (Railroad)						
Sprinkler System						















⁽¹⁾Flags, paint on pavement, wooden stakes, etc.

Drilling or Excavation Sites. Attach a map of the property showing the proposed drilling or excavation site (or if sites are widely separated, several maps) clearly indicating the area(s) checked for underground utilities or underground structures and the location of above-ground power lines.

RECORD OF SUBSURFACE EXPLORATION										
 <div>EA Engineering, Science, and Technology, Inc. 405 S. Highway 121 Building C, Suite 100 Lewisville, Texas 75067</div>		Well/Boring #:		Date Drilled:						
		Depth of Boring:		Diameter of Boring:						
		Length of Casing:		Diameter of Casing:						
		Length of Screen:		Slot Size:						
		Screen Material:		Filter Pack:						
Project:		 Concrete		 Clay		 Limestone				
Logged By:		 Bentonite		 Silt		 Shale				
Drilling Co.:		 Filter Pack		 Sand		 Sandstone				
Driller:		 Well Screen		 Gravel		 Peat/Coal				
Drilling Method:										
Depth (Feet)	 Water Level	GEOLOGIC DESCRIPTION		USCS LOG	Well Completion and Lithology			OVM ppm	LEL (%)	BLOW COUNTS
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
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19										
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21										
22										
23										
24										
25										
26										
27										
28										
29										
30										

RECORD OF SUBSURFACE EXPLORATION									
 <div>EA Engineering, Science, and Technology, Inc. 405 S. Highway 121 Building C, Suite 100 Lewisville, Texas 75067</div>		Well/Boring #:		Date Drilled:					
		Depth of Boring:		Diameter of Boring:					
		Length of Casing:		Diameter of Casing:					
		Length of Screen:		Slot Size:					
		Screen Material:		Filter Pack:					
Project:		 Concrete		 Clay		 Limestone			
Logged By:		 Bentonite		 Silt		 Shale			
Drilling Co.:		 Filter Pack		 Sand		 Sandstone			
Driller:		 Well Screen		 Gravel		 Peat/Coal			
Drilling Method:									
Depth (Feet)	 Water Level	GEOLOGIC DESCRIPTION		USCS LOG	Well Completion and Lithology		OVM ppm	LEL (%)	BLOW COUNTS
30									
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46									
47									
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49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									

RECORD OF SUBSURFACE EXPLORATION									
 <div>EA Engineering, Science, and Technology, Inc. 405 S. Highway 121 Building C, Suite 100 Lewisville, Texas 75067</div>		Well/Boring #:		Date Drilled:					
		Depth of Boring:		Diameter of Boring:					
		Length of Casing:		Diameter of Casing:					
		Length of Screen:		Slot Size:					
		Screen Material:		Filter Pack:					
Project:		 Concrete		 Clay		 Limestone			
Logged By:		 Bentonite		 Silt		 Shale			
Drilling Co.:		 Filter Pack		 Sand		 Sandstone			
Driller:		 Well Screen		 Gravel		 Peat/Coal			
Drilling Method:									
Depth (Feet)	 Water Level	GEOLOGIC DESCRIPTION		USCS LOG	Well Completion and Lithology		OVM ppm	LEL (%)	BLOW COUNTS
60									
61									
62									
63									
64									
65									
66									
67									
68									
69									
70									
71									
72									
73									
74									
75									
76									
77									
78									
79									
80									
81									
82									
83									
84									
85									
86									
87									
88									
89									
90									

RECORD OF SUBSURFACE EXPLORATION										
 <div>EA Engineering, Science, and Technology, Inc. 405 S. Highway 121 Building C, Suite 100 Lewisville, Texas 75067</div>		Well/Boring #:		Date Drilled:						
		Depth of Boring:		Diameter of Boring:						
		Length of Casing:		Diameter of Casing:						
		Length of Screen:		Slot Size:						
		Screen Material:		Filter Pack:						
Project:		<div><div> Concrete</div><div> Clay</div><div> Limestone</div><div> Bentonite</div><div> Silt</div><div> Shale</div><div> Filter Pack</div><div> Sand</div><div> Sandstone</div><div> Well Screen</div><div> Gravel</div><div> Peat/Coal</div></div>								
Logged By:										
Drilling Co.:										
Driller:										
Drilling Method:										
Depth (Feet)	 Water Level	GEOLOGIC DESCRIPTION			USCS LOG	Well Completion and Lithology		OVM ppm	LEL (%)	BLOW COUNTS
90										
91										
92										
93										
94										
95										
96										
97										
98										
99										
100										
101										
102										
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115										
116										
117										
118										
119										
120										

Site: West County Road 112 Ground Water Pl		Client: EPA Region 6 RAC 2 Contract	
Project No.: 14342.65	Sample ID:		Well No.:
Development Start Date/Time:		Development End Date/Time:	
Developed By:			

Original DTW Final DTW

Average Development Rate: _____ gpm Weather _____

[illegible]

* All depths in feet below reference point on wellhead, generally Top of Casing; DTW = Depth to Water

Appendix D
Proposed Schedule

Task Order Schedule																																																
EPA REGION 6, RAC2, Contract EP-W-06-004, 0064-RICO-A6R6																																																
West County Road 112 Ground Water Plume Superfund Site Remedial Investigation/Feasibility Study																																																
ID	WBS	Task Name	Start	Finish	Duration	Predecessors	2011												2012												2013																	
							3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter								
							Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun					
0	0	West County Road 112 RI/FS Project Plan	Mon 7/26/10	Thu 5/30/13	1040 days																																											
1																																																
2	1	RI/FS Task Order	Mon 7/26/10	Mon 9/27/10	64 days																																											
3	1.1	Issue Task Order	Mon 7/26/10	Mon 7/26/10	1 day																																											
4	1.1	Contractor Develop Work Plan	Tue 7/27/10	Tue 8/24/10	29 days	3																																										
5	1.1	EPA Review/Negotiate Work Plan Costs	Wed 8/25/10	Mon 9/27/10	34 days	4																																										
6	1.1	EPA Approval of Work Plan	Mon 9/27/10	Mon 9/27/10	0 days	5																																										
7	3	Remedial Investigation (Tasks 1, 3-9)	Tue 9/28/10	Thu 2/23/12	514 days	6																																										
8	3.2	Site Plans (Task 1)	Tue 9/28/10	Thu 11/10/11	409 days																																											
9	1	Site Plans Phase I	Tue 9/28/10	Sat 11/13/10	47 days																																											
10	1.2.1	Draft SAP/HASP	Tue 9/28/10	Wed 10/27/10	30 days	6																																										
11	1.2.1	EPA Review	Thu 10/28/10	Mon 11/8/10	12 days	10																																										
12	1.2.1	SAP Revision 00	Tue 11/9/10	Sat 11/13/10	5 days	11																																										
13	1.5	Draft Conceptual Understanding of the Site Technical Memorandum (CUSTM)	Tue 9/28/10	Wed 10/27/10	30 days	6																																										
14	1.5	EPA Review	Thu 10/28/10	Mon 11/8/10	12 days	13																																										
15	1.5	CUSTM Revision 00	Tue 11/9/10	Sat 11/13/10	5 days	14																																										
16	1	Site Plans Phase II (Task 1)	Wed 1/26/11	Mon 2/28/11	34 days																																											
17	1.2.1	Draft SAP Revision 01	Wed 1/26/11	Wed 2/9/11	15 days	45,49																																										
18	1.2.1	EPA Review	Thu 2/10/11	Wed 2/23/11	14 days	17																																										
19	1.2.1	SAP Revision 01	Thu 2/24/11	Mon 2/28/11	5 days	18																																										
20	1.5	Draft CUSTM Revision 01	Wed 1/26/11	Wed 2/9/11	15 days	17SS																																										
21	1.5	EPA Review	Thu 2/10/11	Wed 2/23/11	14 days	20																																										
22	1.5	CUSTM Revision 01	Thu 2/24/11	Mon 2/28/11	5 days	21																																										
23	1	Site Plans Phase III (Task 1)	Thu 6/2/11	Sat 8/13/11	73 days																																											
24	1.2.1	Draft SAP Revision 02	Sat 6/4/11	Fri 6/17/11	14 days	57FS+2 days																																										
25	1.2.1	EPA Review	Mon 6/20/11	Fri 7/1/11	12 days	24FS+2 days																																										
26	1.2.1	SAP Revision 02	Sat 7/2/11	Wed 7/6/11	5 days	25																																										
27	1.5	Draft CUSTM Revision 02	Sat 6/4/11	Fri 6/17/11	14 days	24SS																																										
28	1.5	EPA Review	Mon 6/20/11	Fri 7/1/11	12 days	27FS+2 days																																										
29	1.5	CUSTM Revision 02	Sat 7/2/11	Wed 7/6/11	5 days	28																																										
30	1.2.3	Draft Pilot Test Work Plan	Thu 6/2/11	Sat 7/16/11	45 days	57																																										
31	1.2.3	EPA Review	Mon 7/18/11	Fri 7/29/11	12 days	30FS+1 day																																										
32	1.2.3	Final Pilot Test Work Plan	Sat 7/30/11	Sat 8/13/11	15 days	31																																										
33	1	Site Plans Phase IV (Task 1)	Mon 10/10/11	Thu 11/10/11	32 days																																											
34	1.2.1	Draft SAP Revision 03	Mon 10/10/11	Mon 10/24/11	15 days	62																																										
35	1.2.1	EPA Review	Tue 10/25/11	Sat 11/5/11	12 days	34																																										
36	1.2.1	SAP Revision 03	Sun 11/6/11	Thu 11/10/11	5 days	35																																										
37	1.5	Draft CUSTM Revision 03	Mon 10/10/11	Mon 10/24/11	15 days	34SS																																										
38	1.5	EPA Review	Tue 10/25/11	Sat 11/5/11	12 days	37																																										
39	1.5	CUSTM Revision 03	Sun 11/6/11	Thu 11/10/11	5 days	38																																										
40	3	Field Investigation	Tue 9/28/10	Thu 2/23/12	514 days																																											
41	3	Phase I (Task 3)	Fri 10/1/10	Wed 3/2/11	153 days																																											
42	3	Private Well Sampling	Mon 11/29/10	Wed 1/19/11	52 days																																											
43	3.4	Sample Private Wells	Mon 11/29/10	Sat 12/4/10	6 days	12FS+15 days																																										
44	4.1	Lab Analysis - Prelim Data	Mon 12/6/10	Tue																																												

						TASK ORDER SCHEDULE EPA REGION 6, RAC2, Contract EP-W-06-004, 0064-RICO-A6R6 West County Road 112 Ground Water Plume Superfund Site Remedial Investigation/Feasibility Study																																						
ID	WBS	Task Name	Start	Finish	Duration	Predecessors	2011												2012												2013													
							3rd Quarter				4th Quarter				1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter		
							Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
58	3	Phase III (Task 3)	Tue 7/12/11	Sun 10/9/11	90 days																																							
59	3.3	Well Installation	Tue 7/12/11	Wed 8/10/11	30 days	26FS+5 days																																						
60	3.4	Well Sampling	Thu 8/11/11	Thu 8/25/11	15 days	59																																						
61	4.1	Lab Analysis - Prelim Data	Fri 8/26/11	Sat 9/3/11	9 days	60																																						
62	4.1	Lab Analysis - Final Data	Fri 8/26/11	Sun 10/9/11	45 days	60																																						
63	3.3	Aquifer Testing	Thu 8/18/11	Mon 8/22/11	5 days	59FS+7 days																																						
64	8	Pilot Test (Task 8)	Sun 8/14/11	Thu 2/23/12	194 days																																							
65	8	Well Installation	Sun 8/14/11	Tue 8/23/11	10 days	32																																						
66	8	Collect Baseline Samples	Wed 8/24/11	Tue 8/30/11	7 days	65																																						
67	8	Product Injections	Wed 8/31/11	Tue 9/6/11	7 days	66																																						
68	8	Pilot Test Monitoring & Analysis	Wed 9/7/11	Tue 1/24/12	140 days	67																																						
69	8	Prepare and Submit ISCR Tech Memo	Wed 1/25/12	Thu 2/23/12	30 days	68																																						
70	3	Phase IV (Task 3)	Tue 9/28/10	Tue 12/28/10	92 days																																							
71	3.3	Well Installation	Tue 9/28/10	Wed 10/27/10	30 days																																							
72	3.4	Well Sampling	Sat 10/30/10	Sat 11/13/10	15 days	71FS+2 days																																						
73	4.1	Lab Analysis - Prelim Data	Sun 11/14/10	Mon 11/22/10	9 days	72																																						
74	4.1	Lab Analysis - Final Data	Sun 11/14/10	Tue 12/28/10	45 days	72																																						
75	3	Phase V (Task 3) (optional)	Sat 1/22/11	Tue 3/22/11	60 days																																							
76	3.4	Well Sampling	Sat 1/22/11	Sat 2/5/11	15 days	73FS+60 days																																						
77	4.1	Lab Analysis - Prelim Data	Sun 2/6/11	Mon 2/14/11	9 days	76																																						
78	4.1	Lab Analysis - Final Data	Sun 2/6/11	Tue 3/22/11	45 days	76																																						
79	3	Phase VI (Task 3) (optional)	Sat 4/16/11	Wed 6/29/11	75 days																																							
80	3.4	Well Sampling	Sat 4/16/11	Sat 4/30/11	15 days	77FS+60 days																																						
81	4.1	Lab Analysis - Prelim Data	Sun 5/1/11	Mon 5/9/11	9 days	80																																						
82	4.1	Lab Analysis - Final Data	Sun 5/1/11	Wed 6/29/11	60 days	80																																						
83																																												
84	6	Data Evaluation (Task 6)	Wed 12/29/10	Sun 2/13/11	47 days																																							
85	6.1	Draft Data Evaluation Tech Memo	Wed 12/29/10	Thu 1/27/11	30 days	74																																						
86	6.1	EPA Review	Fri 1/28/11	Tue 2/8/11	12 days	85																																						
87	6.1	Final Data Evaluation Tech Memo	Wed 2/9/11	Sun 2/13/11	5 days	86																																						
88																																												
89	9	Remedial Investigation (RI) Report (Task 9)	Mon 2/14/11	Sat 5/14/11	90 days																																							
90	6.2	Develop Ground Water Flow Model	Mon 2/14/11	Wed 3/30/11	45 days	74,87																																						
91	7.1	Develop Draft Risk Assessment	Mon 2/14/11	Wed 3/30/11	45 days	90SS																																						
92	9.1	Develop and Submit Draft RI Report	Mon 2/14/11	Wed 3/30/11	45 days	91SS																																						
93	9	EPA Review of RI Report	Sat 4/2/11	Wed 4/20/11	19 days	92FS+2 days																																						
94	9	Submit Final RI Report	Sat 4/23/11	Fri 5/13/11	21 days	93FS+2 days																																						
95	9	EPA Approval of Final RI Report	Sat 5/14/11	Sat 5/14/11	1 day	94																																						
96																																												
97	10	Feasibility Study (Tasks 10-12)	Thu 3/31/11	Sun 9/11/11	165 days																																							
98	10	Remedial Alternatives Screening and Evaluation (Tasks 10 and 11)	Thu 3/31/11	Mon 7/4/11	96 days																																							
99	6.2.2	Ground Water Model Remedial Simulations	Thu 3/31/11	Mon 5/9/11	40 days	90																																						
100	10.6	Develop and Submit Remedial Alternatives Tech Memo (RATM)	Tue 5/17/11	Wed 6/15/11	30 days	95FS+2 days																																						
101	10.6	EPA Approval of Final RATM	Thu 6/16/11	Mon 7/4/11	19 days	100																																						
102																																												
103	12	Feasibility Study (FS) Report	Tue 7/5/11	Sun 9/11/11	69 days																																							
104	12																																											

Appendix E

Standard Operating Procedures



Standard Operating Procedure No. 001 for Sample Labels

Prepared by

EA Engineering, Science, and Technology, Inc.
11019 McCormick Road
Hunt Valley, Maryland 21031

Revision 0
August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for the use of sample labels. Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. An example label is provided below. Other formats with similar levels of detail are acceptable.

PROJECT NAME _____ PROJECT NUM. _____
SAMPLE LOCATION/SITE ID _____
DATE: ____/____/____ TIME: ____:____
ANALYTES: METALS VOC EXPLOSIVES ORGANICS OTHER
FILTERED: [NO] [YES]
PRESERVATIVE: [NONE] [HNO₃] [OTHER _____]
SAMPLER: _____

2. MATERIALS

The following materials may be required: sample label and indelible laboratory marker.

3. PROCEDURE

The following sections describe how to use the sample labeling system.

3.1 LABEL INFORMATION

As each sample is collected/selected, fill out a sample label. Enter the following information on each label:

- Project name
- Project number
- Location/site identification—Enter the media type (i.e., well number, surface water, soil, etc.) sampling number, and other pertinent information concerning where the sample was taken
- Date of sample collection

- Time of sample collection
- Analyses to be performed (NOTE: Due to number of analytes, details of analysis should be arranged with laboratory *prior to start of work*)
- Whether filtered or unfiltered (water samples only)
- Preservatives (water samples only)
- Number of containers for the sample (e.g., 1 of 2, 2 of 2).

3.2 ROUTINE CHECK

Double-check the label information to make sure it is correct. Detach the label, remove the backing, and apply the label to the sample container. Cover the label with clear tape, ensuring that the tape completely encircles the container.

3.3 RECORD INFORMATION

Record the sample number and designated sampling point in the field logbook, along with the following sample information:

- Time of sample collection (each logbook page should be dated)
- Location of the sample
- Organic vapor meter or photoionization meter readings for the sample (when appropriate)
- Any unusual or pertinent observations (oily sheen on groundwater sample, incidental odors, soil color, grain size, plasticity, etc.)
- Number of containers required for each sample
- Whether the sample is a quality assurance sample (split, duplicate, or blank).

3.3.1 Logbook Entry

A typical logbook entry might look like this:

- 7:35 a.m. Sample No. MW-3. PID = 35 ppm
- Petroleum odor present. Sample designated MW-3-001.

NOTE: Duplicate samples will be given a unique sample designation rather than the actual sample number with an added prefix or suffix. This will prevent any indication to the laboratory that this is a duplicate sample. This fictitious sample number will be listed in the logbook along with the actual location of the sample.

3.4 SHIPMENT

Place the sample upright in the designated sample cooler. Make sure there is plenty of ice in the cooler at all times.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

5.1 INCIDENTAL ODORS

Note that although incidental odors should be noted in the logbook, it is unwise from a safety and health standpoint to routinely “sniff test” samples for contaminants.

5.2 DUPLICATE SAMPLE

No indication of which samples are duplicates is to be provided to the laboratory.

6. REFERENCES

U.S. Environmental Protection Agency. 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. QAMS-005/80.



Standard Operating Procedure No. 002 for Chain-of-Custody Form

Prepared by

EA Engineering, Science, and Technology, Inc.
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August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for use of the chain-of-custody form. An example is provided as Figure SOP002-1. Other formats with similar levels of detail are acceptable.

2. MATERIALS

The following materials may be required: chain-of-custody form and indelible ink pen.

3. PROCEDURE

- Give the site name and project name/number.
- Enter the sample identification code.
- Indicate the sampling dates for all samples.
- List the sampling times (military format) for all samples.
- Indicate “grab” or “composite” sample with an “X.”
- Specify the sample location.
- Enter the total number of containers per cooler.
- List the analyses/container volume.
- Obtain the signature of sample team leader.
- State the carrier service and airbill number, analytical laboratory, and custody seal numbers.
- Sign, date, and time the “relinquished by” section.
- Upon completion of the form, retain the shipper copy, and affix the other copies to the inside of the sample cooler, in a zip-seal bag to protect from moisture, to be sent to the designated laboratory.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS


None.

6. REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans, QAMS-005/80.

U.S. EPA. 1990. Sampler's Guide to the Contract Laboratory Program. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C. December.

U.S. EPA. 1991. User's Guide to the Contract Laboratory Program. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January.

Company Name:				Project Manager or Contact:		Parameters/Method Numbers for Analysis														Chain of Custody Record			
Project No.				Phone:		 EA Laboratories 19 Loveton Circle Sparks, MD 21152 Telephone: (410) 771-4950 Fax: (410) 771-4077														Report Deliverables: 1 2 3 4 D E EDD: Yes/No DUE TO CLIENT: _____			
Dept.: Task:				Project Name:																			
Sample Storage Location:				ATO Number:																			
Page of			Report #:			No. of Containers														EA Labs Accession Number		Remarks	
Date	Time	Water	Soil	Sample Identification 19 Characters																LPM:			



Standard Operating Procedure No. 003 for Subsurface/Utility Clearance

Prepared by

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1. SCOPE AND APPLICATION

1.1 PURPOSE

The purpose of this Standard Operating Procedure is to prevent injury to workers and damage to subsurface structures (including tanks, pipe lines, water lines, gas lines, electrical service, etc.) during ground disturbance activities (including drilling, augering, sampling, use of direct-push technologies, excavation, trenching, concrete coring or removal, fence post installation, grading, or other similar operations).

1.2 LIMITATIONS

The procedures set forth in this document are the suggested procedures but may not be applicable to particular sites based on the site-specific considerations. The Project Manager is responsible for making a site-specific evaluation of each site to determine whether the Subsurface/Clearance Procedures should be utilized or require modification. If safety or other site-specific considerations require a modified or different procedure, the Project Manager should review the modified procedure with the Business Unit Director, Profit Center Manager, or Senior Technical Reviewer.

1.3 SCOPE

This procedure provides minimum guidance for subsurface clearance activities, which must be followed prior to and during ground disturbance activities at EA project sites. Even after completing the subsurface clearance activities required in this procedure, all ground disturbance activities should proceed with due caution.

Deviations from this procedure may be provided on an exception basis for specific situations, such as underground storage tank systems removals, verified aboveground/overhead services/lines, undeveloped land/idle facilities, shallow groundwater conditions, soil stability, or well construction quality assurance/quality control concerns, etc.

EA or its subcontractors are responsible for, and shall ensure that, all ground disturbance activities are completed safely, without incident, and in accordance with applicable federal, state, and local regulations.

This procedure shall not override any site-specific or consultant/contractor procedures that are more stringent or provide a greater degree of safety or protection of health or the environment.

2. PROCEDURES

The EA Project Manager or his designee must complete the Subsurface Clearance Procedure Checklist (Appendix A) in conjunction with the following procedures. The checklist must be completed before initiating any ground disturbance activities. The completed checklist must be submitted to the appropriate team individuals, subcontractors, and/or the client and included in the project files.

2.1 SAFETY

A Health and Safety Plan must be available onsite and followed by all contractors and subcontractors.

All work areas shall be defined and secured with safety cones, safety tape, construction fence, other barriers, or signs as appropriate.

Site work permits must be obtained as required by site procedures. Based on site conditions or classification, the use of intrinsically-safe equipment may be required.

To ensure the safety of all onsite personnel and subsurface structure integrity, consideration should be given to de-energizing and locking out selected site utilities or temporarily shutting down a portion of or the entire facility.

2.2 PREPARATION TASKS

Objective—To gather all relevant information about potential subsurface structures prior to the actual site visit.

2.2.1 Obtain Permits and Site Access

The consultant/contractor is responsible for following all applicable laws, guidance, and approved codes of practice; obtaining all necessary permits and utility clearances; and securing site access permission.

2.2.2 Historic Site Information

Obtain most recent as-built drawings and/or site plans (including underground storage tank, product, and vent lines) as available.

NOTE: As-built drawings may not accurately depict the locations and depths of improvements and subsurface structures and should, therefore, not be **solely** relied upon.

EA should obtain any other site information such as easements, right-of-ways, historical plot plans, fire insurance plans, tank (dip) charts, previous site investigations, soil surveys, boring logs, and aerial photographs, etc. as relevant to the planned ground disturbance activities.

Where applicable, EA should also contact contract personnel who may have historic site knowledge.

2.2.3 Mark-Outs

Objective—To identify location of subsurface structures on surface.

EA must ensure that a thorough mark-out at the site is completed to locate electrical, gas, telephone, water, sewer, low voltage electric lines, product delivery pipelines, fiber optic, and all other subsurface utilities/services.

- Where available, public utility companies must be contacted to identify underground utilities. (This can be accomplished through the One-Call system in most instances.)
- In addition, where available and warranted by site conditions, a private utility/pipeline mark-out company should be contracted to perform an electronic subsurface survey to identify the presence of suspected hazardous or critical underground utilities and subsurface structures. In some cases, this is necessary to confirm public utility mark-outs in the vicinity of planned ground disturbance activities.

EA will review all available site plan subsurface information with the private mark-out company to assist in locating utilities and other subsurface structures.

NOTE: Mark-outs may not accurately depict the exact locations of improvements and subsurface structures and should, therefore, not be **solely** relied upon.

Where possible, EA personnel are encouraged to be onsite at the time of subsurface mark-outs. This is to ensure accuracy and understanding of subsurface structures identified and provides an opportunity to exchange information with mark-out company personnel regarding planned work activities.

Subsurface structures should be marked throughout the entire work area(s) with adequate materials (e.g., site conditions may require paint and tape/flags). Ground disturbance activities must be started within 30 days of mark-out, unless local ordinances specify a shorter time period. If activities are not started within required time period or markings have faded, mark-outs must be redone.

EA personnel will record time and date of mark-out request and list all companies contacted by the service and confirmation number. This should be available for review onsite and checked off after visual confirmation of markings.

2.2.4 Initial Site Visit

Objective—To compare the site plan to actual conditions based on information gathered in Procedures 2 and 3 above, obtain additional site information needed, and prepare a vicinity map.

EA will document all findings and update the site plan with this information. On third party sites, close coordination with the site owner's representatives for mark-outs, review of as-builts, and other information reviews should be conducted prior to work. Project Managers are encouraged to provide updated as-built information to the client.

In some regions, it may be more effective and efficient to conduct the site visit at the same time the contractor and drill rig are mobilized to the site. The inspection should include the following activities and may include others as determined by the consultant/contractor and the Project Manager.

2.2.5 Utilities

EA shall perform a detailed site walk-through for the purpose of identifying all aboveground indicators of subsurface utilities/services that may be leading to or from buildings within the planned work area. The inspection shall include, but not be limited to, the following:

- Utility mark-outs
- Aboveground utilities
- Area lights/signs
- Phones
- Drains
- Junction boxes
- Natural gas meters or connections
- Other utilities including: fire hydrants, on/below grade electrical transformers, splice cages, sewer lines, pipeline markers, cable markers, valve box covers, clean-outs/traps, sprinkler systems, steam lines (including insulated tanks that may indicate steam lines), and cathodic protection on lines/tanks
- Observe paving scars (i.e., fresh asphalt/concrete patches, scored asphalt/concrete).

NOTE: In many cases, the onsite location of low-voltage electrical lines and individual property water and sewer line branches may be approximated by using the following technique:

- Locate the entry/connection location at the facility building
- Attempt to identify utility connections for the mains (water sewer, etc.) by locating clean-outs, valve manways, etc. The location path of the utility is likely with the area between the main connection and facility building connection. Subsurface electrical line locations from the facility building to signs, lamps, etc. can be estimated with the same process.

2.2.6 Other Subsurface Systems

Some other subsurface systems to be cognizant of during subsurface activities include product delivery systems (i.e., at gas stations) and existing remediation systems.

2.2.7 Selection of Ground Disturbance Locations

EA will utilize the information collected to this point in combination with regulatory requirements and project objectives to select ground disturbance locations. Ground disturbance locations should also consider the location of overhead obstructions (e.g., power lines). Work at active gasoline retail locations must consider several special considerations that should be outlined in the site-specific safety and health plan.

2.2.8 Review of Selected Locations with the Client

EA will review the selected ground disturbance locations with the client. EA will not proceed with the subsurface activities until the plan has been discussed with the client. During execution of the project, subsurface activities are required outside of the area previously approved by the client. EA will submit these changes to the client for approval prior to execution.

2.2.9 Ground Disturbance Activity Sequence

EA will plan ground disturbance activities starting at the point farthest from the location of suspected underground improvements. This is done to determine the natural subsurface conditions and to allow EA site personnel to recognize fill conditions.

Experience has shown that the following warning signs may indicate the presence of a subsurface structure:

- Warning tape (typically indicative of underground services).
- Pea gravel/sand/non-indigenous material (typically indicative of tanks or lines).
- Red concrete (typically indicative of electrical duct banks).

- The abrupt absence of soil recovery in a hand auger. This could indicate pea gravel or sand that has spilled out of the auger. This may not be indicative in areas where native soil conditions typically result in poor hand auger recoveries.
- Any unexpected departure from the native soil or backfill conditions as established by prior onsite digging.

If any of these conditions is encountered by EA site personnel, digging should stop and the client should be contacted.

3. SUBSURFACE CLEARANCE METHODS

The method used to delineate the subsurface should be compatible with the inherent associated risk given the type of facility/property, soil stratigraphy, and the location of the ground disturbance activity, such that required delineation is obtained. It should be noted that in areas where there is paving, sufficient paving should be removed to allow clear visibility of the subsurface conditions during clearance activities. The following is a list of potential clearance methods that may be used on a job site:

- Vacuum digging
- Probing
- Hand digging
- Hand augering
- Post-hole digging.

EA personnel will evaluate the potential for electrical shock or fire/explosion for each subsurface disturbance project and will evaluate as necessary the use of non-conductive or non-sparking tools (i.e., fiberglass hand shovels, and thick electrically insulating rubber grips on hand augers or probes). The potential need for the use of non-conductive materials, electrical safety insulated gloves, and footwear will also be evaluated on a case-by-case basis.

3.1 SUBSURFACE CLEARANCE PROCEDURES FOR DRILLING, DIRECT-PUSH TECHNOLOGY, AUGERING, FENCE POST INSTALLATION, OR OTHER BOREHOLE INSTALLATION ACTIVITIES

The area to be delineated will exceed the diameter of the largest tool to be advanced and sufficiently allow for visual inspection of any obstructions encountered.

3.2 SUBSURFACE CLEARANCE PROCEDURES FOR TRENCHING/ EXCAVATION ACTIVITIES

Appropriate subsurface clearance methods should be conducted along the length and width of the excavation at a frequency sufficient to ensure adequate precautions have been applied to the entire work area. The frequency and density of investigations will be based on site knowledge, potential hazards, and risks of the work area to surrounding locations (e.g., proximity to a residential area or school).

Whenever subsurface structures are exposed, EA will cease work and mark the area (e.g., flags, stakes, cross bracing) to ensure the integrity of these exposed structures is maintained during subsequent trenching/excavation/backfilling.

Uniform color codes for marking of underground facilities are provided in Appendix B.

Appendix A

Subsurface Clearance Procedure Checklist

Subsurface Clearance Procedure Checklist

Site Identification: _____

Project Consultant/Contractor: _____

Section 1: Safety, Preparation Tasks, and Mark-Outs

Activity	Yes	No	N/A	Comments including Justification if Response Is No or Not Applicable
Health and Safety Plan is available and all contractors and subcontractors are familiar with it.				
All applicable local, state, and federal permits have been obtained.				
Site access/permission has been secured.				
Most recent as-built drawings and/or site plans (including underground storage tank, product, and vent lines) obtained.				
Reviewed site information to identify subsurface structures relevant to planned site activities (easements, rights-of-way, historical plot plans, fire insurance plans, tank dip charts, previous site investigations, soil surveys, boring logs, aerial photographs, etc.).				
Utility mark-outs have been performed by public utility company(s). Mark-outs clear/visible.				
Subsurface structure mark-outs performed by private mark-out company. Mark-outs clear/visible.				
Additional Activities: Were dig locations reviewed with site representative?				

Section 2: Initial Site Visit and Selecting Ground Disturbance Locations

Activity	Yes	No	N/A	Comments including Justification if Response Is No or Not Applicable
Location of all aboveground indicators of subsurface utilities/services that may be leading to or from buildings within the planned work area has been identified.				
Location of utility mark-outs by all utility companies previously contacted has been identified within required time period.				
Location of all subsurface structure mark-outs by private mark-out company has been identified within required time period.				
Location of area lights/signs and associated subsurface lines identified.				
Location of all phones and associated subsurface lines identified.				
Location of all drains and associated interconnecting lines identified.				
Location of all electrical junction boxes and associated interconnecting lines identified				
Location of all natural gas meters or connections and all interconnecting lines identified				

Completed by: _____

Name

Signature: _____

Company

Date

Appendix B

Uniform Color Codes for Excavation

UNIFORM COLOR CODE

	WHITE - Proposed Excavation
	PINK - Temporary Survey Markings
	RED - Electric Power Lines, Cables, Conduit and Lighting Cables
	YELLOW - Gas, Oil, Steam, Petroleum or Gaseous Materials
	ORANGE - Communication, Alarm or Signal Lines, Cables or Conduit
	BLUE - Potable Water
	PURPLE - Reclaimed Water, Irrigation and Slurry Lines
	GREEN - Sewers and Drain Lines

TYPICAL MARKING

LARGE PIPE OR MULTIPLE DUCTS

SMALL PIPE OR CABLE(S)

* REFER TO TEXT ON FRONT OF CARD

Customize with your center's
phone and address information

GUIDELINES FOR UNIFORM TEMPORARY MARKING OF UNDERGROUND FACILITIES

This marking guide provides for universal use and understanding of the temporary marking of subsurface facilities to prevent accidents and damage or service interruption by contractors, excavators, utility companies, municipalities or any others working on or near underground facilities.

ONE-CALL SYSTEMS

The One-Call damage prevention system shall be contacted prior to excavation.

PROPOSED EXCAVATION

Use white marks to show the location, route or boundary of proposed excavation. Surface marks on roadways do not exceed 1.5" by 18" (40 mm by 450 mm). The facility color and facility owner identity may be added to white flags or stakes.

USE OF TEMPORARY MARKING

Use color-coded surface marks (i.e., paint or chalk) to indicate the location or route of active and out-of-service buried lines. To increase visibility, color coded vertical markers (i.e., stakes or flags) should supplement surface marks. Marks and markers indicate the name, initials or logo of the company that owns or operates the line, and width of the facility if it is greater than 2" (50 mm). Marks placed by other than line owner/operator or its agent indicate the identity of the designating firm. Multiple lines in joint trench are marked in tandem. If the surface over the buried line is to be removed, supplementary offset markings are used. Offset markings are on a uniform alignment and clearly indicate the actual facility is a specific distance away.

TOLERANCE ZONE

Any excavation within the tolerance zone is performed with non-powered hand tools or non-invasive method until the marked facility is exposed. The width of the tolerance zone may be specified in law or code. If not, a tolerance zone including the width of the facility plus 18" (450 mm) measured horizontally from each side of the facility is recommended.

ADOPT UNIFORM COLOR CODE

The American Public Works Association encourages public agencies, utilities, contractors, other associations, manufacturers and all others involved in excavation to adopt the APWA Uniform Color Code, using ANSI standard Z535.1 Safety Colors for temporary marking and facility identification.

Rev. 4/99



Standard Operating Procedure No. 004 for Sample Packing and Shipping

Prepared by

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August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for the packing and shipping of samples to the laboratory for analysis.

2. MATERIALS

The following materials may be required:

Clear tape	Plastic garbage bags
Custody seals	Sample documentation
Ice	Waterproof coolers (hard plastic or metal)
Metal cans with friction-seal lids (e.g., paint cans)	Zip-seal plastic bags
Packing material ¹	

3. PROCEDURE

Check cap tightness and verify that clear tape covers label and encircles container. Wrap sample container in bubble wrap or closed cell foam sheets. Enclose each sample in a clear zip-seal plastic bag.

Place several layers of bubble wrap, or at least 1 in. of vermiculite on the bottom of the cooler. Line cooler with open garbage bag, place all the samples upright inside a garbage bag, and tie the bag.

Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the ice outside the garbage bags containing the samples.

Pack shipping containers with packing material (closed-cell foam, vermiculite, or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment.

Enclose all sample documentation (i.e., Field Parameter Forms, chain-of-custodies) in a waterproof plastic bag and tape the bag to the underside of the cooler lid. If more than one cooler is being used, each cooler will have its own documentation.

Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal.

-
1. Permissible packing materials are: (a) (non-absorbent) bubble wrap or closed cell foam packing sheets, or (b) (absorbent) vermiculite. Organic materials such as paper, wood shavings (excelsior), and cornstarch packing "peanuts" will not be used.

Refer to SOP Nos. 001, 002, 016, and 039.

Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain.
Ship all samples via overnight delivery on the same day they are collected if possible.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Any samples suspected to be of medium/high contaminant concentration or containing dioxin must be enclosed in a metal can with a clipped or sealable lid (e.g., similar to a paint can). Label the outer metal container with the sample number of the sample inside.

6. REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans, QAMS-005/80.

U.S. EPA. 1990. Sampler's Guide to the Contract Laboratory Program. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C. December.

U.S. EPA. 1991. User's Guide to the Contract Laboratory Program. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January.



Standard Operating Procedure No. 005 for Field Decontamination

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1. SCOPE AND APPLICATION

All personnel or equipment involved in intrusive sampling, or which enter a hazardous waste site during intrusive sampling, must be thoroughly decontaminated prior to leaving the site to minimize the spread of contamination and prevent adverse health effects. This Standard Operating Procedure describes the normal decontamination of sampling equipment and site personnel.

2. MATERIALS

The following materials may be required:

0.01N HCl	Non-phosphate laboratory detergent (liquinox)
0.10N nitric acid	Plastic garbage bags
Aluminum foil or clean plastic sheeting	Plastic sheeting, buckets, etc. to collect wash water and rinsates
Approved water	Pressure sprayer, rinse bottles, brushes
High performance liquid chromatography (HPLC)-grade water ¹	Reagent grade alcohol ²

3. PROCEDURE

3.1 SAMPLE BOTTLES

At the completion of each sampling activity, the exterior surfaces of the sample bottles must be decontaminated as follows:

- Ensure the bottle lids are on tight.
- Wipe the outside of the bottle with a paper towel to remove gross contamination.

3.2 PERSONNEL DECONTAMINATION

Review the project Health and Safety Plan for the appropriate decontamination procedures.

-
1. For the purposes of this Standard Operating Procedure, HPLC-grade water is considered equivalent to “deionized ultra filtered water,” “reagent-grade distilled water,” and “deionized organic-free water.” The end product being water which is pure with no spurious ions or organics to contaminate the sample. The method of generation is left to the individual contractor.
 2. For the purposes of this Standard Operating Procedure, the term “reagent grade alcohol” refers to either pesticide grade isopropanol or reagent grade methanol.

3.3 EQUIPMENT DECONTAMINATION

3.3.1 Water Samplers

3.3.1.1 Bailers

After each use, polytetrafluoroethylene (PTFE) double check valve bailers used for groundwater sampling will be decontaminated as follows:

- Discard all ropes used in sampling in properly marked sealable container, or as directed by the Health and Safety Plan. NOTE: No tubing is to be used in conjunction with a bailer in collecting samples.
- Scrub the bailer to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate detergent.
- Rinse off detergent three times with approved water.
- Rinse bailer with reagent grade alcohol.
- Rinse bailer three times with HPLC-grade water.
- Rinse bailer with 0.10N nitric acid solution.
- Rinse bailer three times with HPLC-grade water.
- Allow bailer to air dry.³
- Wrap bailer in aluminum foil or clean plastic sheeting, or store in a clean, dedicated polyvinyl chloride or PTFE storage container.
- Dispose of used decontamination solutions with drummed purge water.
- Rinse bailer with HPLC-grade water immediately prior to re-use.

3.3.1.2 Pumps

Submersible pumps will be decontaminated as follows:

-
3. If the bailer has just been used for purging and is being decontaminated prior to sampling, do not air dry. Double rinse with HPLC-grade water and proceed to collect samples.

- Scrub the exterior of the pump to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate detergent. (Steam cleaning may be substituted for detergent scrub.)
- Calculate the volume of pump plus any tubing which is not disposable and not dedicated to a single well. Pump three volumes of non-phosphate laboratory detergent solution to purge and clean the interior of the pump.
- Rinse by pumping no less than nine volumes of approved water to rinse.
- Rinse pump exterior with reagent grade alcohol.
- Rinse pump exterior with HPLC-grade water.
- Allow pump to air dry.
- Wrap pump in aluminum foil or clean plastic sheeting, or store in a clean, dedicated polyvinyl chloride or PTFE storage container.
- Prior to reusing pump rinse exterior again with HPLC-grade water. (Double rinse in Bullet 5 above may be substituted for this step).

3.3.1.3 Dip Samplers

All dip samplers, whether bucket, long-handled, or short-handled, will be decontaminated in the same manner as provided in Section 3.3.1.1.

3.3.1.4 Labware

Labware, such as beakers, which are used to hold samples for field measurements, water chemistry, etc. will be decontaminated according to the procedures in Section 3.3.1.1.

3.3.1.5 Water Level Indicators

Electric water level indicators, weighted measuring tapes, or piezometers used in the determination of water levels, well depths, and/or non-aqueous phase liquid levels will be decontaminated in accordance with Section 3.3.1.1. Clean laboratory wipes may be substituted for brushes. Tapes, probes, and piezometers should be wiped dry with clean laboratory wipes, and coiled on spools or clean plastic sheeting rather than allowed to air dry.

3.3.2 Solid Materials Samplers

Solid materials samplers include soil sampling probes, augers, trowels, shovels, sludge samplers, and sediment samplers, which will be decontaminated as follows:

- Scrub the sampler to remove gross (visible) contamination, using appropriate brush(es), approved water, and non-phosphate laboratory detergent.
- Rinse off detergent with approved water.
- Rinse sampler with reagent grade alcohol.
- Rinse sampler with HPLC-grade water.
- For non-metallic samplers only, rinse sampler with 0.10N nitric acid solution.
- For non-metallic samplers only, rinse sampler with HPLC-grade water.
- Allow sampler to air dry.
- Wrap sampler in aluminum foil clean plastic sheeting, or store in a new zipseal bag (size permitting) or clean, dedicated polyvinyl chloride or PTFE storage container.
- Dispose used decontamination solutions properly according to the site-specific Health and Safety Plan.
- Rinse sampler with HPLC-grade water immediately prior to re-use.

3.3.3 Other Sampling and Measurement Probes

Soil gas sampling probes will be decontaminated as solids sampling devices.

Temperature, pH, conductivity, redox, and dissolved oxygen probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contaminant and triple rinse probe with HPLC-grade water. A summary of the decontamination procedures to be used must be included in the instrument-specific standard operating procedure.

Measuring tapes that become contaminated through contact with soil during field use will be decontaminated as follows:

- Wipe tape with a clean cloth or laboratory wipe that has been soaked with non-phosphate laboratory detergent solution to remove gross contamination. Rinse cloth in the solution and continue wiping until tape is clean.
- Wipe tape with a second clean, wet cloth (or laboratory wipe) to remove soap residues.
- Dry tape with a third cloth (or laboratory wipe) and rewind into case, or re-coil tape.

3.3.4 Drilling Rigs and Other Heavy Equipment

All drilling rigs and associated equipment such as augers, drill casing, rods, samplers, tools, recirculation tank, and water tank (inside and out) will be decontaminated prior to site entry after over-the-road mobilization and immediately upon departure from a site after drilling a hole. Supplementary cleaning will be performed prior to site entry when there is a likelihood that contamination has accumulated on tires and as spatter or dust enroute from one site to the next.

- Place contaminated equipment in an enclosure designed to contain all decontamination residues (water, sludge, etc.).
- Steam clean equipment until all dirt, mud, grease, asphaltic, bituminous, or other encrusting coating materials (with the exception of manufacturer-applied paint) have been removed.
- Water used will be taken from an approved source.
- Containerize in 55-gal drums; sample; characterize; and, based on sample results, dispose of all decontamination residues properly.

Other heavy equipment includes use of backhoes, excavators, skid steers, etc. If heavy equipment is utilized during field activities, i.e., a backhoe for test pitting, the bucket should not come in contact with soil to be sampled. If the bucket contacts the soil to be sampled, then it should be decontaminated between sample locations, following the same procedures as listed above for a drill rig.

3.3.5 High Performance Liquid Chromatography-Grade Water Storage

Dedicated glass storage containers will be used solely for dispensing HPLC-grade water. New HPLC-grade water containers will be decontaminated as follows:

- Clean with tap water from approved source and non-phosphate laboratory detergent while scrubbing the exterior and interior of the container with a stiff-bristled brush.
- Rinse thoroughly with approved water.
- Rinse with 0.01N nitric acid.
- Rinse with approved water.
- Rinse thoroughly with HPLC-grade water.
- Fill clean container with HPLC-grade water. Cap with one layer of PTFE-lined paper and one layer of aluminum foil. Secure cap with rubber band and date the container.

Used HPLC-grade water containers will be decontaminated as follows:

- Clean the exterior with tap water from an approved source, non-phosphate laboratory detergent, and a stiff-bristled brush.
- Rinse the exterior thoroughly with HPLC-grade water.
- Rinse the interior twice with pesticide-grade isopropanol.
- Rinse interior thoroughly with HPLC-grade water.
- Fill clean container with HPLC-grade water. Cap with one layer of PTFE-lined paper and one layer of aluminum foil. Secure cap with rubber band and date the container.

3.3.6 Ice Chests and Reusable Shipping Containers

- Scrub exterior/interior with approved brush and liquinox detergent.
- Rinse off detergent three times with approved water.
- Let air dry and properly store until re-use.

NOTE: If container/ice chest is severely contaminated, clean as thoroughly as possible, render unusable, and properly dispose.

4. MAINTENANCE

HPLC-grade water will be stored only in decontaminated glass containers with aluminum foil lids as stipulated above. The water may not be stored for more than nor used more than 3 days after manufacture.

HPLC-grade water will be manufactured onsite. An approved tap water source will be used as the influent to the system. Procedures for system setup, operation, and maintenance will conform to manufacturer's specifications.

5. PRECAUTIONS

Dispose of all wash water, rinse water, rinsates, and other sampling wastes (tubing, plastic sheeting, etc.) in properly marked, sealable containers, or as directed by the Health and Safety Plan.

Once a piece of equipment has been decontaminated, be careful to keep it in such condition until needed.

Do not eat, smoke, or drink onsite.

6. REFERENCES

Site-specific Health and Safety Plan.



Standard Operating Procedure No. 008 for pH Measurement

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the pH of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. As a measure of the hydrogen ion content of a solution, pH gives a general indication of the acidity or alkalinity of a water sample.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Φ ® 12 pH Meter
Automatic temperature compensator (ATC) probe
Beakers
Combination (pH) electrode
Commercial buffer solutions (standards) of pH 4.00, 7.00, and 10.00
HPLC-grade water
Laboratory wipes for blotting electrodes
Wash bottle

3. PROCEDURE

3.1 CALIBRATION CHECK

Calibration of the pH meter will be checked on a daily basis. A two-point calibration should be used as follows:

1. Prepare beakers of buffer solutions of pH 4.00, 7.00, and 10.00.
2. Calibration should closely bracket the expected pH range of the samples to be taken.
3. Turn on instrument, clear instrument.
4. Rinse the electrode with distilled water and blot excess.
5. Immerse probes in beaker of pH 4.00 or 7.00 standard, swirl gently.
6. Press pH key, then STD key.

7. Keep the probes in the sample until the reading stabilizes. The reading should be the pH of the standard.
8. Rinse the electrode with distilled water and blot excess.
9. Repeat the procedure with pH 7.00 and 10.00 standards.
10. Record the initial readings.
11. If the measured values vary from the expected value by greater than 0.2 pH units, recalibrate the instrument with fresh aliquots of buffer solution. If the discrepancy persists, alert the Field Operations Leader, who has the option of trying to fix the meter or obtaining a second pH meter.
12. Record all measurements in the field logbook.
13. Verify calibration by reading the pH of the third buffer solution.
14. Refer to SOP No. 016.

3.2 pH MEASUREMENTS

Measurements of pH will be taken using the two-point standardization method as follows:

1. Connect the ATC and pH electrodes to the appropriate inputs.
2. Turn on instrument, clear instrument.
3. Prepare two small beakers of standard buffer solutions. Ideally, the pH values of these standards will “bracket” the expected pH value of the sample and be as close as possible to the pH of the sample.
4. Rinse a small beaker with distilled water, then sample water. Fill the beaker with sample water.
5. Rinse the probes with distilled water. Blot excess.
6. Immerse electrode and ATC in first standard. Swirl gently. Press pH key and STD key. Wait for display to stop flashing.
7. Rinse the probes with distilled water. Blot excess.
8. Immerse electrode and ATC in second standard. Swirl gently. Press STD key. Wait for display to stop flashing.

9. Rinse the probes with distilled water. Blot excess.
10. Immerse the probes in the sample and swirl gently, keeping the probes in the sample until the display stops flashing.
11. Record the sample pH and temperature after stabilization. Note any problems such as meter drift.
12. Rinse the probes with distilled water. Blot excess.
13. Repeat Steps 9 through 12 for additional samples.

Decontaminate probe according to manufacturer's specifications.

Decontaminate beakers according to SOP No. 005, Section 3.3.1.4 (Labware).

4. MAINTENANCE

The following steps will be taken to maintain the pH meter:

1. Check the batteries each time the meter is used.
2. Keep the probe stored in a 0.1 M KCl solution adjusted to pH 4 when the meter is not in use. Alternatively, the electrode may be rinsed with deionized water and the protective cap put on, trapping any residual water inside it (do not blot the electrode dry prior to putting the cap on).

5. PRECAUTIONS

Remove coatings of oil material or particulate matter that can impair electrode response by gentle wiping or detergent washing, followed by distilled water rinsing.

As noted in Section 1, these procedures may not apply to alternate manufacturer's equipment.

Calibration is always performed using the pH 7.00 and one end point (pH4.00 or 11.00) standard. **Never** calibrate the instrument using two end points only.

6. REFERENCES

Beckman Instruments, Inc. Users Manual for Φ° 10 pH Meter, Φ° 11 pH meter, and Φ° 12 pH/ISE Meter.

Franston, M.H. et al. (eds). 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. American Public Health Association, American Water Works Association and Water Pollution Control Federation.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.



Standard Operating Procedure No. 009 for Temperature Measurement

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the temperature of a solid or liquid sample, in particular, for measuring water temperature. Groundwater temperature does not vary dramatically over the course of a year. Therefore, groundwater temperature can be used to help identify an aquifer, identify stream reaches where groundwater inflow is occurring, identify thermal gradients in lakes or ponds, and also indicate when sufficient water has been removed from a well during purging.

2. MATERIALS

The following materials may be required: digital reading thermocouple thermometer in combination meter or in a stick. Accuracy = $\pm 0.5^{\circ}\text{C}$.

3. PROCEDURE

Rinse the probe with distilled water. Insert the probe into the sample, and leave it in the sample until the temperature stabilizes. Record the temperature reading, being sure to indicate $^{\circ}\text{C}$ or $^{\circ}\text{F}$. Decontaminate the probe according to Section 3.3 of SOP No. 005 (Field Decontamination).

Refer to SOP Nos. 005 and 016.

NOTE: $^{\circ}\text{C} = (^{\circ}\text{F} - 32) (5/9)$
 $^{\circ}\text{F} = ([9/5]^{\circ}\text{C}) + 32$.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

None.

6. REFERENCES

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.



Standard Operating Procedure No. 010 for Water Level and Well Depth Measurements

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring water level and well depth. This procedure is applicable to the sampling of monitoring wells and must be performed prior to any activities which may disturb the water level, such as purging or aquifer testing.

2. MATERIALS

The following materials may be required:

Electric water level indicator (dipmeter) with cable measured at 0.01-ft increments OR weighted steel tape and chalk OR transducer and datalogger
Oil/water interface probe
Plastic sheeting
Photoionization detector or intrinsically safe flame ionization detector

3. PROCEDURE

3.1 PRELIMINARY STEPS

Locate the well and verify its position on the site map. Record whether positive identification was obtained, including the well number and any identifying marks or codes contained on the well casing or protective casing. Gain access to the top of the well casing.

Locate the permanent reference mark at the top of the casing. This reference point will be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure to the top of the highest point of the well casing and so note this fact in the field logbook. Determine from the records and record in the notebook the elevation of this point.

Record any observations and remarks regarding the completion characteristics and well condition, such as evidence of cracked casing or surface seals, security of the well (locked cap), and evidence of tampering.

Keep all equipment and supplies protected from gross contamination; use clean plastic sheeting. Keep the water level indicator probe in its protective case when not in use.

3.2 OPERATION

Sample the air in the well head for gross organic vapors by lifting the well cap only high enough for an organic vapor meter (photoionization detector or flame ionization detector) probe to be entered into the well casing. This will indicate the presence of gross volatile contaminants as well as indicating potential sampler exposure.

Remove cap. Allow well to vent for 60-90 seconds. Resample headspace. Record both readings. If the second reading is lower than the first, use the second reading to determine whether respiratory protection will be required during subsequent water level and well depth determinations, and sampling.

Note that all headspace sampling must be performed at arm's length and from the upwind side of the well if possible.

Refer to SOP Nos. 011, 023, or 024 as appropriate.

If non-aqueous phase liquid (NAPL) contamination is suspected¹, use an interface probe to determine the existence and thickness of NAPLs.

Open the probe housing, turn the probe on, and test the alarm. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates a NAPL while an intermittent alarm indicates water. If a NAPL is detected, record the initial level (first alarm). Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable sufficiently to record the depth.

Continue to slowly lower the probe until it passes into the water phase. Slowly retract the probe until the NAPL alarm sounds and record that level in the manner as described above.

Record the thickness of the light NAPL² (Section 3.3).

Continue to slowly lower the interface probe through the water column to check for the presence of dense NAPL.

Measure and record the thickness of the dense NAPL layer (if any) as described above.

Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensors and re-check the depths.

NOTE: Air/liquid interface depth is more reliable if probe is lowered into liquid. NAPL/water depths are more accurate if probe is moved from water into NAPL.

Always lower and raise interface probe slowly to prevent undue mixing of media.

-
1. Interface probes will be used in all wells for first round sampling, regardless of site history. If no NAPLs are detected during the first round of sampling, this step may be omitted during subsequent sampling events **unless** conditions such as site history or headspace vapors would indicate otherwise.
 2. If NAPL is viscous, such as coal tar or weather bunker oil, several confirmation measurements should be made after decontamination of the probe to verify that the NAPL is not sticking to the probe and causing erroneous readings. One way to accomplish this would be to partially fill a 5-gal bucket with water and dip the probe to ensure that decontamination has effectively removed the NAPL.

Always perform NAPL check in wells installed in areas with suspected NAPL contamination. Always perform NAPL check if headspace test reveals presence of volatiles. Always perform NAPL check the first time a well is sampled. **If** a well has been sampled previously **and** no NAPLs were present **and** none of the preceding conditions are met, the NAPL check may be omitted.

If no NAPL is present, use an electronic water level detector as follows:

- Remove the water level indicator probe from the case, turn on the sounder, and test check the battery and sensitivity scale by pushing the red button. Adjust the sensitivity scale until you can hear the buzzer.
- Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering until the meter buzzes. Very slowly, raise and lower the probe until the point is reached where the meter **just** buzzes. Marking the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable and record the depth.

Alternatively use a steel tape with an attached weight if aquifer gradients are lower than 0.05 ft/ft. Due to the possibility of adding unknown contaminants from chalk colorants, only white chalk is permitted.

Rub chalk onto the first 1 ft of the steel tape and slowly lower the chalked end into the well until the weighted end is below the water surface. (A small splash can be heard when the weighted end hits the water surface.)

Using the method described above read and record the length from the steel tape.

Remove the steel tape. The chalk will be wet or absent where the tape was below the water surface. Locate, read, and record this length. Subtract wetted length from total length and record the difference. This is the depth to water table.

Transducers and dataloggers will be used where water level fluctuations over time are to be measured, such as tidal fluctuation studies (SOP No. 045) and aquifer (hydraulic) tests (SOP No. 033). Note that transducers are inappropriate for measuring well depth.

Slowly lower the transducer into the well until it is below the lowest possible piezometric level (typically 2-3 ft below the water table).

Tape the umbilical to the protective casing to prevent the transducer from falling further.

Attach the umbilical leads to the datalogger.

Turn datalogger on.

To measure the well depth, lower electric water level indicator probe or tape until slack is noted. Very slowly raise and lower the cable until the exact bottom of the well is “felt.” Measure (cable) or read the length (tape) and record the depth.

Note that if the electric water level indicator is used to determine depth of well, the offset distance between the tip of the probe and the electrode must be added to the reading to determine actual depth.

Withdraw the probe or tape. Decontaminate the probe(s) and cable(s).

3.3 DATA RECORDING AND MANIPULATION

Record the following computations:

- Date and time
- Weather
- Method of measurement
- Casing elevation
- NAPL surface elevation = casing elevation – depth to NAPL
- NAPL thickness = depth to bottom of NAPL – depth to top of NAPL
- Water level elevation = casing elevation – depth to water
- Well bottom elevation = casing elevation – depth to bottom (or read directly from tape).

Refer to SOP Nos. 005 and 016.

4. CALIBRATION

No calibration is needed.

5. PRECAUTIONS

Depending upon the device used, correction factors may be required for some measurements. Check instrument batteries prior to each use. Exercise care not to break the seals at the top of the electric water level indicator probe.

6. REFERENCES

- McAlary, T.A. and J.F. Barker. 1987. Volatilization Losses of Organics during Groundwater Sampling from Low Permeability Materials in Groundwater Monitoring Review. Fall.
- Thornhill, J.T. 1989. Accuracy of Depth to Groundwater Measurements in U.S. Environmental Protection Agency Superfund Groundwater Issue EPA/540/4-89/002.



Standard Operating Procedure No. 012 for Specific Conductance Measurements

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the specific conductance of any aqueous solution, including drinking water, saline water, and industrial and domestic wastes. Conductivity is the ability of an aqueous solution to pass an electrical current. The current is primarily carried by dissolved inorganic ions such as chlorides, nitrates, sulfates, along with cations such as sodium, calcium, magnesium and others. Organic compounds do not carry current and, therefore, have almost no conductivity.

2. MATERIALS

The following materials may be required:

Conductivity meter with integral temperature compensation; accuracy = ± 2 percent at 25°C (77°F)
Conductivity cell
Appropriate conductivity reference solution
High performance liquid chromatography (HPLC)-grade water (see SOP No. 005, Footnote 2)
Thermometer (optional, Section 5)

3. PROCEDURE

3.1 CALIBRATION

The specific conductivity meter should be calibrated at the beginning of each day¹ as follows:

1. Thoroughly rinse the probe with appropriate conductivity reference solution.
2. Zero meter if appropriate.
3. Measure the specific conductance of fresh appropriate conductivity reference solution record it in the field notebook, and adjust the calibration knob until the meter reads properly.
4. Rinse probe with HPLC-grade water.
5. Measure the specific conductance of HPLC-grade water and record in the field logbook. If specific conductivity of HPLC-grade water is not 0 (± 2 percent) recalibrate instrument.

1. The meter should be recalibrated any time the readings are suspect (e.g., out of expected range).

3.2 OPERATION

The specific conductivity meter will be operated as follows:

1. Thoroughly rinse the probe and sample beaker with sample water.
2. Measure the temperature of the sample water. Convert Fahrenheit temperature readings to Celsius using $C = 5/9(F - 32)$ if Celsius temperature is not obtained directly.
3. Place the probe in the sample beaker with sufficient sample to completely submerge the probe. Swirl the probe to remove any air bubbles trapped in the probe.
4. Select the highest multiplier scale on the meter and turn the instrument on. Progressively use lower multiplier scales until a mid-scale deflection is obtained.
5. If appropriate, check probe accuracy by pressing cell test button. If value change is >10 percent check probe.
6. Record the temperature and conductivity values.
7. Specific conductivity values are corrected for temperature using:

$$K^{25^{\circ}\text{C}} = \{K \text{ measured}\} \text{ over } \{1 + 0.0191 (t-25)\}$$

where

K = Conductivity in μmhos
t = Temperature, $^{\circ}\text{C}$

8. Decontaminate the probe (see SOP No. 005, Section 3.3.3).

Refer to SOP Nos. 005 and 016.

4. MAINTENANCE

The following steps will be taken to properly maintain the conductivity meter:

1. Check the batteries each time the instrument is used.
2. Inspect the probe on a daily basis for damage or loss of platinum black plating from the electrode. If the platinum is damaged, alert the Field Team Leader and arrange to get a new cell.
3. Follow manufacturer's specifications regarding storage of probe between uses.

5. PRECAUTIONS

Be certain there is no air in the cell before taking a reading. If conductivity meter does not have integral temperature compensation, use a thermometer to determine temperature of the sample.

6. REFERENCES

Manufacturer's Manual.

U.S. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. March.



Standard Operating Procedure No. 013 for Collection of Monitoring Well Samples

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for the collection of groundwater samples from monitoring wells.

2. MATERIALS

The following materials may be required:

0.45 μ M filters	Polyvinyl chloride bailer (for purging only)
Bladder pump (dedicated to one well only)	Sample bottles and labels
Conductivity meter	Stainless steel bailer (for purging and sampling)
Dissolved oxygen meter	Submersible pump and hose (for purging only)
Generator	Thermometer (optional) ¹
Logbook or book of field parameter forms	Transparent bailer with a double check valve
Peristaltic pump with tubing for filtering samples	Turbidity meter
pH meter with oxidation-reduction potential probe	Tygon tubing
Photoionization detector organic vapor analyzer.	Variable speed, low flow submersible pump (e.g., Grundfos MP1 groundwater sampling pump) (for purging and sampling)
Plastic sheeting	Water level indicator
Polypropylene rope	
Polytetrafluoroethylene (PTFE) bailer with PTFE-coated stainless steel cable, double check valve top, and controlled flow bottom discharge attachment ² for volatile organic compound (VOC) sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles) (for purging and sampling)	

3. PROCEDURE

3.1 GENERAL

Groundwater sampling will follow these general steps:

- Arrive onsite
- Set up apparatus (generators, pumps, etc.)
- Glove
- Organic vapor check, water level, and well depth measurements

1. Temperature compensation and measurement capabilities are generally available as integral functions of pH meters and conductivity meters. If this is the case, a separate thermometer is not required.
2. Although use of a controlled flow bottom discharge valve is historically preferred, use of such a device can cause aeration of the sample.

- Sample non-aqueous phase liquids (NAPLs) (as required)
- Begin purge procedure
 - If using bailer to purge and sample, see Section 3.6
 - If using pump to purge and bailer to sample, see Section 3.7
 - If using bladder or low-flow pump to purge and sample, see Section 3.8
- Decontaminate/reglove
- Take samples
 - If with bailer, see Section 3.6
 - If with bladder or low flow pumps, see Section 3.8
- Decontaminate/dispose of wastes, move equipment to next site.

3.2 GENERAL RULES FOR GROUNDWATER FIELD PARAMETER LOGBOOK

Only one site or installation per logbook, and only one sampling location per page or form (if using pre-printed forms). The same book may be used for more than one sampling event. First five pages will be reserved for index, general notes, etc. Sign and date each entry. Last five pages will be reserved for recording calibration data for the pH, temperature, turbidity, oxidation-reduction potential, dissolved oxygen, and conductivity meters. Use the page number or a separately recorded “Cal Reference Number” to refer to each calibration. As appropriate, insert the cardboard flap under the form being filled out, so that writing does not go through to the pages below. As appropriate, fill in the forms from front to back of the logbook, tearing out the white copy for each sample when the sample has been collected. This copy goes in the cooler with the sample, directly to the laboratory. The original copy must be torn out before you write on the back of the duplicate form. As appropriate, duplicate copies, index pages, and calibration sheets remain intact.

3.3 GROUNDWATER SAMPLING GENERAL RULES

Groundwater samples will be collected from the least contaminated wells first, progressing to the most contaminated³. Upon arrival at the well site, immediately set up and organize the purging, sampling, and filtration equipment. If needed, due to muddy or contaminated ground, remoteness from sampling vehicle, and/or for placement of hose(s) and/or power cord if a pump is used, place clean plastic sheeting at, or around the well, to serve as a clean staging area for purging and sampling equipment, as conditions warrant. Care must be exercised not to step on plastic sheeting. If the well is remote from the sampling vehicle, set up the filtration equipment

3. First round samples are to be collected from upgradient wells first, moving to downgradient wells under the assumption that upgradient wells will be less contaminated than downgradient wells. Results of first round analysis may mandate a change in sampling sequence.

and place rope, wrapped bailer, and pre-labeled sample containers on the plastic sheet, from the well. When a pump is to be used, situate the portable generator on level ground approximately 15 ft away from and downwind from the well. All generator maintenance (oil and fueling) is to be performed offsite. If the hose(s) and/or power cord of the pump are not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

Check well headspace for organic vapor which may pose a health and safety hazard and indicate the presence of NAPL. Measure depth(s) to and thickness(es) of NAPL(s) as appropriate. Measure the depth to water and depth of well. From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

1 EV = volume in casing + volume in saturated sand pack. Therefore, if the water table lies below the top of the sandpack, use the following equation:

$$1 \text{ EV} = (\pi R_w^2 h_w) + (0.30\pi(R_s^2 - R_w^2)h_w) * (0.0043)$$

If the water table lies above the top of the sandpack use this equation:

$$1 \text{ EV} = [(\pi R_w^2 h_w) + (0.30\pi(R_s^2 - R_w^2)h_s)] * (0.0043)$$

where

R_s = Radius of sandpack in inches
 R_w = Radius of well casing in inches
 h_s = Height of sandpack in inches
 h_w = Water depth in inches

0.0043 gal/in.³

Assumed filter pack porosity = 30 percent.

Samples will always be collected in order of decreasing volatility (i.e., the samples to be analyzed for the volatile constituents should be collected first). Deliver the VOC sample to the vial by allowing the water to trickle down the inside wall of the vial at a rate no greater than approximately 100 ml/min. Other samples may be delivered at a faster rate. Sampling rates will at no time exceed 1 L/min. Procedures for each class of samples are contained in the site-specific Quality Assurance Project Plan.

When collecting samples for volatile analysis, care should be taken to prevent analyte loss by volatilization. The following procedures should be adhered to when collecting these samples:

- Avoid excessive aeration and agitation of sample.
- Fill vial so that a reverse meniscus is present by adjusting the flow rate from the sampling device.

- Place septum on vial so that the PTFE side is in contact with the sample. After the cap is on the bottle, check for air bubbles in the sample. If air bubbles are present, properly dispose of that sample and recollect the sample in the same vial.
- Make sure vial is labeled and immediately transfer the vial to the cooler with ice.

Filtered and unfiltered samples will be taken for inorganics (metals) analyses. The samples will be filtered through an in-line 0.45- μ M filter (preferred method), or by gravity through a 0.45- μ M membrane placed in a filter funnel. Use forceps to place the membrane into the funnel and pour sample through funnel until appropriate volumes have been filtered.

If necessary, due to slow filtering, a peristaltic pump may be used to filter the sample through an in-line filter. Connect the pump to the generator, attach tygon tubing to the bottom discharge valve on the bailer. Start pump and collect sample from the end of the in-line filter directly into the proper container, preserved, and placed in the cooler. Filtered samples will be preserved in the field with acid to a pH of less than 2. Make sure sample bottle is labeled and the cap is on tightly. Then place in cooler with ice immediately.

— OR —

If a low flow pump is used collect the samples, filtered samples will be taken by installing a 0.45- μ M filter in-line and pumping the water through the filter. Collect sample from the end of the in-line filter directly into the proper container, preserved, and placed in the cooler. Filtered samples will be preserved in the field with acid to a pH of less than 2. Make sure sample bottle is labeled and the cap is on tightly. Then place in cooler with ice immediately.

Unfiltered samples will be collected by slowly pouring the sample water into the appropriate sample container, being careful not to agitate or cause bubbles to form. Do not overfill bottles. Make sure sample bottle is labeled and the cap is on tightly, then place the sample in cooler with ice immediately.

All samples will be delivered to the laboratory as soon as possible. If possible, samples will be shipped on the same day as they are collected. If samples must be retained due to weekend sampling (Friday through Sunday), the laboratory will be notified as to the time sensitive nature of the samples.

3.4 SAMPLING OF NON-AQUEOUS PHASE LIQUIDS

If NAPLs are detected in the well, a sample from all layers must be collected prior to any purging activities. NAPLs may be indicated by the presence of volatiles in the well headspace, and confirmed by the oil/water interface probe.

Collecting light non-aqueous phase liquid (LNAPL) will be accomplished using a transparent bailer with a double check valve. This bailer will be slowly lowered until the bottom of the bailer is 1-2 in. below the LNAPL-water interface, then slowly withdrawn. Verify that the interface was sampled by visual inspection of the bailer contents through the side of the bailer. Measure the thickness of the LNAPL in the bailer and note in the Field Logbook. Sample for laboratory analysis. An additional field verification may be performed by decanting the remainder of the contents of the bailer into a glass jar, adding a hydrophobic dye such as Sudan IV, or Redoil, shaking the sample and looking for coloration of NAPL. Alternate field tests are: examine the sample under ultraviolet light (many fluoresce), or allow the sample to stand overnight, and examine for interface and/or volatiles in the headspace the following day. Refer to following sections on purging and sample collection for setup and general operation.

Collecting dense non-aqueous phase liquids (DNAPLs) will be accomplished using a transparent bailer with a double check valve. The bailer must be lowered very slowly to the bottom of the well and raised slowly out of the well in a controlled fashion. Sample for analysis as above. The same field check described above may be employed for DNAPL. Refer to following sections on purging and sample collection for set up and general operation.

If NAPLs are present in the well, **and** a low-flow pump is to be used for purging and sampling, the well will be allowed to re-equilibrate prior to purging and sampling. This will be accomplished by allowing the well to stand undisturbed for at least 8 hours prior to purging and sample collection.

3.5 WELL PURGING GENERAL RULES

Water within the casing of a well will stagnate, degas, lose volatiles, possibly precipitate metals due to changes in redox potential, and may react with the screen and/or casing material. It is, therefore, necessary to purge a sufficient volume of this stagnant water from the well and/or casing to ensure that a representative sample of formation water can be obtained. Traditionally, the volume of water to be purged was arbitrarily set at 3-5 equivalent volumes. Recent advances in sampling technologies have caused a re-thinking of such arbitrary purge volumes. It is for this reason that monitoring of select chemical and physical properties of the sample medium will be used instead of strict volumes to determine when a representative sample may be taken from a well.

Acceptable purge/sampling devices include: bailers, high-discharge submersible pumps (purge only), and variable speed, low-flow pumps which include both submersible pumps (purge and sample) and dedicated bladder pumps (purge and sampling). It is recommended to purge and sample at similar rates with one type device per well. An acceptable exception to this general rule is to use a high-discharge submersible pump to purge a deep, fast-recharging well, and a bailer to sample the same well.

Peristaltic, gas-lift, and centrifugal pumps can cause volatilization, produce high pressure differentials, and can result in variability in the analysis of some analytes of interest. These types of pumps will not be used to purge or sample wells.

To prevent groundwater from cascading down the sides of the screen into an open hole, thereby aerating the sample, purge rates will closely match recharge rates. If the static water level is within the casing, the initial purge rates may be set high enough to lower the water level to the top of the screen, then reduced to maintain that level.

Purging will be accomplished with either a submersible pump, a low-flow (submersible or bladder) pump, or bailer. The choice of bailer or pump will be based on depth to water table, volume to be purged, and permeability of the aquifer. If the well recharges rapidly and/or has greater than 20 gal (estimated EV) to be purged, water may be removed with a submersible pump or a low-flow pump. If the well recharges slowly and/or has less than 20 gal to be purged, water will be removed with a bailer or a low-flow pump.

Purging will be accomplished with as minimal disturbance to the surrounding formation as possible.

Purge water will be containerized onsite until analysis of samples is completed. Based on sample results, accumulated purge water will be properly disposed.

If the water level is within the screened interval and the well recharge rate is less than 0.1 L/min, purge the well using a low-flow pump as follows:

1. Draw the water down to within 1 ft of the top of the pump.
2. Allow the well to recover.
3. Check and record field parameters.
4. Repeat Steps 1 through 3 then collect samples for metals analysis only⁴.
5. Note the event in the Field Logbook, and report the problem to the Project Manager. If this extremely low recharge problem consistently occurs in a given well, the well may be considered for re-development and/or replacement.
6. If adjacent wells have elevated VOC levels, additional soil gas surveys will be considered in the vicinity of the low recharge well to help determine the need for replacement.

3.6 PURGING AND SAMPLING WITH BAILERS

Bailers may be used for both purging and sampling wells if: (a) the well recharge rate is less than 4 L/min, (b) depth to the water table is less than 50 ft, and (c) less than 20 gal are to be purged (5 EV < 20 gal)⁵.

4. Analyte losses due to volatilization in a drained well are too high for valid VOC sampling (M^CAlary and Barker 1987).

When purging with a bailer, either a polyvinyl chloride, PTFE, or stainless steel bailer may be used. The bailer will be attached to either a spool of PTFE-coated stainless steel cable or polypropylene rope. If using cable, attach it to the bailer using stainless steel cable clamps. Thoroughly decontaminate the cable after each use, prior to rewinding cable onto spool. Cable clamps and raw cable ends may serve to trap contamination. Exercise particular caution in decontaminating these areas. If using rope, attach the rope to the bailer using a bowline knot, dispense the needed length (a few feet more than the well depth) and cut the remainder away; then, at the end opposite the bailer, make a slip knot and place it around the well casing or protective posts to prevent losing the bailer and rope down the well. The polypropylene rope will be not reused; it will be properly disposed of. Either type of bailer will be repeatedly lowered gently into the well until it fills with water, removed, and the water will be discharged into an appropriate container until purging is complete. Care must be taken not to unduly agitate the water, as this tends to aerate the sample, increase turbidity, makes stabilization of required parameters difficult to achieve, and generally prolongs purging.

After purging 2 EV, obtain a sample of groundwater and measure the following stabilization parameters: temperature, conductivity, pH, turbidity, redox potential (Eh), and dissolved oxygen level at each successive half-well volume. When three of these stabilization parameters are in agreement within approximately 10 percent in three consecutive half-well volume samples, sufficient water has been purged from the well. The results of these tests should be recorded in the sampling logbook. Should these parameters not reach agreement, no more than five well volumes will be purged.

Immediately upon completion of purging, collect samples for laboratory analysis using a PTFE bailer on a PTFE-coated stainless steel cable. The bailer will be equipped with double check valve top and controlled flow bottom discharge attachments for VOC sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles).

Slowly, so as not to agitate the water, lower the bailer into the well, using a spool of PTFE-coated cable. Allow bailer to fill, withdraw smoothly. Refill bailer as needed.

If the controlled flow bottom discharge attachment is used for VOC sampling, attach it to the bottom of the bailer. Using the stopcock valve on the bailer to control the flow, fill sample vials as described above in Section 3.3.

Remove check valve top and pour unfiltered sample into inorganics sample bottles.

Collect filtered samples as described in Section 3.3. Decontaminate bailer and cable.

-
5. These numbers are based on the following assumptions: (1) In purging, it is preferable to remove water at approximately the recharge rate; (2) 4 L/min is estimated as the approximate maximum rate at which water can be removed with a bailer from depths of 20-50 ft; and (3) 20 gal is estimated to be at the limit of the sampler's endurance, at which point fatigue and sloppiness of technique begin.

3.7 PURGING WITH PUMP, SAMPLING WITH BAILER

If the recharge rate of the well is greater than 30 L/min, or the water level is deeper than 50 ft, or more than 20 gal of purge water will be generated ($5 \text{ EV} > 20 \text{ gal}$), then purging and sampling may be accomplished using a submersible pump/bailer combination.

When purging with a pump, gradually lower the intake until it is submerged within the screened interval. Lower an electronic water level probe to the top of the screen (as determined from completion records) to the monitor water level, start pump, and slowly lower the pump as the water level continues to fall. Care should be exercised to lower the water column to the top of the screened interval (water level probe will stop beeping) but not below the top of the screen if possible. This will ensure that the stagnant layer has been removed, but should minimize the detrimental effects of over pumping the well. Secure hose(s) and/or power cord to casing and place discharge hose into the proper container, downhill and as far away from the well as possible. Determine and record the discharge rate.

Discharge rate = volume of container/time to fill container

The discharge rate will be established at approximately equal to or just greater than the well's recharge rate (determined from well development). If well development records are incomplete, recharge rate can be determined by monitoring the rise/fall of the water level within the casing as one purges the well. If the water level is static at a given pumping rate, but fluctuates up or down as pumping rate is decreased or increased, the pumping rate at which the water level is static is the recharge rate.

After purging 2 EV, obtain a sample of groundwater and measure the following stabilization parameters: temperature, conductivity, pH, turbidity, redox potential (Eh), and dissolved oxygen level at each successive half-well volume. When three of these stabilization parameters are in agreement within approximately 10 percent in three consecutive half-well volume samples, sufficient water has been purged from the well. The results of these tests should be recorded in the sampling logbook. Should these parameters not reach agreement, no more than five well volumes will be purged.

Immediately upon completion of purging, collect samples for laboratory analysis using a PTFE bailer on a PTFE-coated stainless steel cable. The bailer will be equipped with double check valve top and controlled flow bottom discharge attachments for VOC sampling (40-mL vials), and top discharge attachment for collecting larger samples (1-L bottles). Filtration of metals samples will be accomplished using either an in-line filter attached to the bottom of the bailer, or a funnel and appropriate filter (Section 3.3).

Slowly, so as not to agitate the water, lower the bailer into the well, using a spool of PTFE-coated cable. Allow bailer to fill, withdraw smoothly, fill sample containers as described in Section 3.6. Decontaminate bailer and cable in and decontaminate pump.

3.8 PURGING AND SAMPLING WITH LOW-FLOW PUMP

To obtain representative samples, subsurface disturbances should be kept to a minimum, thereby preventing sample alteration due to sampling actions. The reasoning behind the use of low-flow pumps to purge and sample monitoring wells is that these pumps minimize physical disturbance (turbulence) at the sampling point and chemical changes (aeration) in the medium. For these reasons, the low-flow pump is the preferred method for both purging and sampling in most cases. For the purposes of this SOP, “low-flow pumps” are defined as either dedicated bladder pumps or variable speed submersible pumps. Practical operational flow rates for these sampling devices range from 0.1 L/min to 30 L/min.

Low-flow pumps may be used for purging and sampling any well having recharge greater than 0.1 L/min, which is the practical lower limit of pump performance. Below that pumping rate, pump inefficiencies and/or overheating may alter the physical and chemical properties of the sample. If the pump is continuously operated at sampling rates higher than the well recharge rate, the water level will be lowered in the well, possibly allowing aeration of the sample which is unacceptable sampling procedure. Low-flow pumps are suitable for sampling wells with recharge rates lower than 0.1 L/min if precautions are taken to avoid aeration of the sample.

Low flow submersible pumps will be used as follows:

- Lower the pump into the well, slowly so as not to agitate the water, until the pump is at the mid-point of the screened interval or the mid-point of the water column if the static water table lies below the top of the screen⁶
- Attach the pump’s umbilical cord (which will consist of power cord and sampling tubing) to the protective casing, or lock the cord spool so that the pump cannot move vertically in the well during sampling.
- Lower the water level probe into the well behind the pump until it just touches water. This will allow the sampler to monitor the water level while purging and sampling, and prevent the inadvertent drying of the well.

6. This assumes a 10-ft screened interval. If the screened interval is greater than 10 ft, multiple samples should be taken as follows:

- If the screen is 10-12 ft, sample the center of the water column, as outlined above.
- If the screen is longer than 12 ft, and the water column is 10 ft or less, sample the center of the water column.
- If the screen is longer than 12 ft, and the water column fills the screen, or extends above the screen, sample at 1/3 and 2/3 the height of the water column, or about every 6 ft.

- Begin purging at the pump's lowest setting, then gradually increase rate⁷ until the pumping rate matches the aquifer recharge rate. **If the water level is above the top of the screen**, the pumping rate may be allowed to slightly exceed recharge rate, lowering the water level to no less than 1 ft above the screen, then reduced until it matches recharge rate and purging continued. **If the water level is below the top of the screen**, always keep the purge rate lower than well's recharge rate.
- Monitor stabilization parameters listed in Section 3.6 beginning immediately, using an in-line monitoring system. Record parameters regularly, at a rate of one set of parameters per each 1-3 liters of water removed from the well. When these parameters stabilize to within 10 percent over three consecutive readings, reduce⁸ flow rate to 0.1 L/min (if needed) and begin collecting VOC samples directly from the discharge line.
- If the well recharges at a rate less than 0.1 L/min, purge until the water level is even with the top of the screen, allow the well to recover, and sample immediately.
- Remove and decontaminate water level probe and pump.

4. MAINTENANCE

Refer to manufacturer's requirements for maintenance of pumps and generators.

5. PRECAUTIONS

Refer to the site-specific Health and Safety Plan for appropriate personal protective equipment.

6. REFERENCES

- Garske, E.E. and M.R. Schock. 1986. An Inexpensive Flow-Through Cell and Measurement System for Monitoring Selected Chemical Parameters in Groundwater.
- Gass, T.E., J.F. Barker, R. Dickhout, and J.S. Fyfe. 1991. Test Results of the Grundfos Groundwater Sampling Pump, in Proceedings of the Fifth National Symposium on Aquifer Restoration and Groundwater Monitoring.

7. Some sources indicate that the pumping rate should not exceed 1 L/min, with 0.5 L/min being preferable. The optimal purge rate is highly aquifer dependent, and may range from less than 0.5 L/min to greater than 10 L/min. The purge rate for a given well will, therefore, be a field decision, based on well development, purge, and sampling records rather than SOP mandate.

8. Sampling should occur at the same rate as purging as long as aeration of sample does not occur.

- McAlary, T. A. and J.F. Barker. 1987. Volatilization Losses of Organics During Groundwater Sampling From Low Permeability Materials, in Groundwater Monitoring Review. Fall.
- Puls, R.W. and R.M. Powell. 1992. Acquisition of Representative Groundwater Quality Samples for Metals, in Groundwater Monitoring Review. Summer.
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- Puls, R.W., R.M. Powell, B. Bledsoe, D.A. Clark, and C.J. Paul. 1992. Metals in Groundwater: Sampling Artifacts and Reproducibility, in Hazardous Waste & Hazardous Materials. Volume 9, No. 2.



Standard Operating Procedure No. 014 for Collection of Production Well Samples

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for the collection of groundwater samples from production wells. This protocol will allow for collection of samples from both active production wells and inactive production wells (Section 3).

2. MATERIALS

The following equipment may be required:

Conductivity meter	pH meter
Dissolved oxygen meter	Sample bottles and labels
Logbook or field parameter form	Temperature meter
Oxidation-reduction potential probe	Turbidity meter

3. PROCEDURE

Upon arrival at the well site, immediately set up and organize the sampling and ancillary equipment. If needed, due to muddy or contaminated ground and/or remoteness from sampling vehicle, place plastic sheeting at or around the sampling location as conditions warrant. Exercise caution not to step on and contaminate the sheeting.

If the well is remote from the sampling vehicle, set up the filtration equipment and place sample containers on the plastic sheet, uphill of the sampling location.

If a pump is to be used for filtration, situate the portable generator on level ground approximately 15 ft away from and downwind from the sampling location. All generator maintenance (oil and fueling) is to be preformed offsite.

If the well is currently in use, as close as possible to the well, open a tap to a high flow rate and allow the well to purge.

Obtain a sample of groundwater for temperature, conductivity, oxidation-reduction potential, dissolved oxygen, turbidity, and pH measurements. Record values in sampling logbook.

Take samples for physical stabilization (water quality) parameters every 5 minutes during the well purging process.

Allow the well to purge until the water quality parameters of pH, temperature, conductivity, turbidity, oxidation-reduction potential, and dissolved oxygen measurements stabilize within 10 percent in three consecutive 5-minute sampling periods, purging will be considered complete and sampling may proceed. Slow water flow rate to a trickle.

For procedures for collecting samples, with the exception of the sample source being a bailer, refer to SOP No. 013.

If the well is not currently in use, use a pump and bailer, or low-flow pump for sampling. Refer to SOP No. 013 for purging and sampling protocol. Decontaminate equipment. Refer to SOP Nos. 001, 002, 004, 005, 013, and 016.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Not applicable.

6. REFERENCES

U.S. Army Toxic and Hazardous Materials Agency. 1990. Installation Restoration Quality Assurance Program, December 1985, 1st Edition, March 1987, 2nd Edition.



**Standard Operating Procedure No. 016
for
Surface Water, Groundwater, and
Soil/Sediment Field Logbooks**

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for recording surface water, groundwater, soil/sediment sampling information, instrument calibration data, and data from hydrologic testing in the field logbooks. Acceptable field logbooks are: bound, unprinted books such as a surveyor's field book, or a federal supply service No. 7530-00-222-3525 record book (or equivalent); or they may be company-proprietary, pre-printed forms bound into a field logbook. Example forms are provided herein. Alternate, equivalent forms are acceptable.

2. MATERIALS

The following material may be required: applicable field logbook and indelible ink pen.

3. PROCEDURE

Information pertinent to soil/sediment, groundwater, or surface water sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. Entries will be made in indelible ink. Corrections will consist of line-out deletions that are initialed and dated. If using carbon paper or self-duplicating forms, before entering data in logbook, insert a sheet protector between form sets to isolate first blank form from remaining forms.

3.1 SOIL/SEDIMENT LOGBOOK (Requires Figures SOP016-1 and SOP016-3)

3.1.1 Field Parameter Form (Items on Figures SOP016-1 and SOP016-2)

1. HIGH CONCENTRATION EXPECTED?: Answer "Yes" or "No."
2. HIGH HAZARD?: Answer "Yes" or "No."
3. SITE: Record the complete name of the site.
4. AREA: Record the area designation of the sample site.
5. INST CODE: Record the 2-letter installation code appropriate for the installation or site. Correct abbreviations can be found on Pages 3-6 of the IRDMS User's Guide for chemical data entry.
6. FILE NAME: Record "CSO" for a soil sample or "CSE" for a sediment sample.
7. SITE TYPE: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on Pages 18-21 of the IRDMS User's Guide for chemical data entry. This entry must match the Site Type on the map file form.

8. SITE ID: Record a code up to 10 characters or numbers which is unique to the site.
9. FIELD SAMPLE NUMBER: Record a code specific for the sample.
10. DATE: Enter the date the sample was taken.
11. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken.
12. AM PM: Circle “AM” or “PM” to designate morning or afternoon (12-hour clock).
13. SAMPLE PROG: Record “GQA” (Groundwater Quality Assessment) or other appropriate sample program.
14. DEPTH (TOP): Record the total depth sampled.
15. DEPTH INTERVAL: Record the intervals at which the plug will be sampled.
16. UNITS: Record the units of depth (feet, meters)
17. SAMPLE MEASUREMENTS: Check the appropriate sampling method.
18. CHK: Check off each container released to a laboratory.
19. ANALYSIS: Record the type of analysis to be performed on each sample container.
20. SAMPLE CONTAINER: Record the sample container type and size.
21. NO.: Record the number of containers.
22. REMARKS: Record any remarks about the sample
23. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers.
24. SITE DESCRIPTION: Describe the location where the sample was collected.
25. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System.
26. COLOR: Record the color of the sample as determined from standard Munsell Color Charts.
27. ODOR: Record the odor of the sample or “none.” See SOP No. 001 Section 5.
28. PID (HNu): Record the measured PID (HNu) values.

29. UNUSUAL FEATURES: Record anything unusual about the site or sample.

30. WEATHER/TEMPERATURE: Record the weather and temperature.

31. SAMPLER: Record your name.

3.1.2 Map File Form (Figure SOP016-3)

1. The map file logbook form will be located on the reverse of the field parameter logbook form, or on an adjoining page of the field logbook (if level book is used).
2. SITE ID: Record the Site ID from the field parameter form.
3. POINTER: Record the field sample number for the sample being pointed to.
4. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks.
5. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks.
6. MAP REFERENCE: Record which U.S. Geological Survey Quad Map references the site.
7. COORDINATE DEFINITION: Write the compass directions the X- and Y-Coordinates of the map run.
8. COORDINATE SYSTEM: Write “UTM” (Universal Transverse Mercator).
9. SOURCE: Record the 1-digit code representing the Map Reference.
10. ACCURACY: Give units (e.g., write “1-M” for 1 meter).
11. X-COORDINATE: Record the X-Coordinate of the sample site location.
12. Y-COORDINATE: Record the Y-Coordinate of the sample site location.
13. UNITS: Record the units map sections are measured in.
14. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey.
15. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference.
16. ACCURACY: Record the accuracy of the map or survey providing the topographical information.

17. ELEVATION: Record the elevation of the sampling site.
18. UNITS: Write the units in which the elevation is recorded.
19. SAMPLER: Write your name.

3.2 SURFACE WATER LOGBOOK (Requires Figures SOP016-2 and SOP016-3)

3.2.1 Field Parameter Form (Items Unique to Figure SOP016-3)

1. CAL REF: Record the calibration reference for the pH meter.
2. pH: Record the pH of the sample.
3. TEMP: Record the temperature of the sample in degrees Celsius.
4. COND: Record the conductivity of the water.
5. For all other sections, see Section 3.2.1.

3.3 GROUNDWATER SAMPLING LOGBOOK (Requires Figures SOP016-2, SOP016-3, and SOP016-4)

3.3.1 Field Parameter Form (Items on Figure SOP016-4)

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on Pages 18-21 of the IRDMS User's Guide for chemical data entry.
2. SAMPLE NO.: Record the reference number of the sample.
3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks.
4. X-COORD and Y-COORD: Record the survey coordinates for the sampling site.
5. ELEV: Record the elevation where the sample was taken.
6. UNITS: Record the units the elevation was recorded in.
7. DATE: Record the date in the form MM/DD/YY.

8. TIME: Record the time, including a designation of AM or PM.
9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit).
10. WELL DEPTH: Record the depth of the well in feet and inches.
11. CASING HT.: Record the height of the casing in feet and inches.
12. WATER DEPTH: Record the depth (underground) of the water in feet and inches.
13. WELL DIAMETER: Record the diameter of the well in inches.
14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches.
15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter.
16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations, to determine one equivalent volume (EV):

1 EV = Volume in casing + volume in saturated sand pack. Or to restate:

$$1 \text{ EV} = (BR_w^2 h_w + 0.30B(R_s^2 - R_w^2)h_s) * (0.0043)$$

where

R_s = Radius of sandpack in inches
 R_w = Radius of well casing in inches
 h_s = Height of sandpack in inches
 h_w = Water depth in inches

$0.0043 = \text{gal/in.}^3$
 and filter pack porosity is assumed as 30 percent

— **OR** —

$$\text{Volume in casing} = (0.0043 \text{ gal/in.}^3)(B)(12 \text{ in./ft})(R_c^2)(W_h)$$

where

R_c = Radius of casing in inches
 W_h = Water column height in feet

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in.}^3)(B)(12 \text{ in./ft})(R_b^2 - R_c^2)(W_h)(0.30)$$

(if W_h is less than the length of the sandpack),

— **PLUS** —

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in.}^3)(B)(12 \text{ in./ft})(R_b^2 - R_c^2)(S_h)(0.30)$$

(if W_h is greater than the length of the sandpack).

where

R_b = Radius of the borehole

S_h = Length of the sandpack.

Show this calculation in the comments section.

17. VOLUME OF BAILER OR PUMP RATE: Record bailer volume or pump rate.
18. TOTAL NUMBER OF BAILERS OR PUMP TIME: Record the number of bailers required to remove 3 equivalent volumes (EV) of water from the well or the total purge time and volume as applicable.
19. WELL WENT DRY? Write “YES” OR “NO.”
20. NUMBER OF BAILERS OR PUMP TIME: Record the number of bailers or pump time which made the well go dry.
21. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry.
22. RECOVERY TIME: Record the time required for the well to refill.
23. PURGE AGAIN?: Answer “YES” or “NO.”
24. TOTAL VOL. REMOVED: Record the total volume of water (in gal) removed from the well.
25. CAL REF.: Record the calibration reference for the pH meter.
26. TIME: Record time started (INITIAL T[0]), 2 times DURING the sampling and the time sampling ended (FINAL).
27. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling and at the end of sampling (FINAL).
28. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).
29. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).

30. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).
31. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).
32. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling and at the end of sampling (FINAL).
33. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace prior to sampling.
34. NAPL: Record the presence and thickness of any non-aqueous phase liquids (light or dense)
35. COMMENTS: Record any pertinent information not already covered in the form.
36. SIGNATURE: Sign the form.

3.4 FIELD CALIBRATION FORMS (Maintained as a separate logbook, or incorporated into sampling logbooks)

3.4.1 Items on Figure SOP016-5

1. Record time and date of calibration. Note whether 12- or 24-hour clock was used.
2. Record calibration standard reference number.
3. Record meter I.D. number
4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line.
5. Record value of reference standard (as required).
6. COMMENTS: Record any pertinent information not already covered on form.
7. SIGNATURE: Sign form.

3.5 GROUNDWATER HYDROLOGY TESTS LOGBOOK (Must include Figures SOP016-6 and SOP016-7 and/or SOP016-8, OR SOP016-9 or SOP016-10)

3.5.1 Field Permeability Test Data Sheet (Items on Figures SOP016-6)

1. CONTRACTOR: Organization performing the test.
2. SEQ. #: Enter page number of this set of forms (page # of #).

3. PROJECT NAME: Record the name assigned by the contractor's organization to the project.
4. PROJECT NO.: Record the contractor assigned project number or the contract number.
5. LOCATION: Specific location
6. CLIENT: Agency or company with the contract under which the work is being performed.
7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.
8. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.
9. TEST TYPE: Short description of the type of test to be performed.
10. RISING/FALLING HEAD WITH SLUG: Check if the test involved the insertion/removal of and inert object.
11. RISING/FALLING HEAD WITHOUT SLUG: Check if the test involved the addition/removal of a quantity of water.
12. START DATE: Date on which the test was begun.
13. CLOCK TIME: Time each datum (depth to groundwater level) is collected. Note whether 12- or 24-hour clock was used.
14. ELAPSED TIME: Time since the last datum was collected.
15. DEPTH TO GWL (ft): Depth to the top of the groundwater table (Groundwater Level) as measured by manual methods.
16. REC. (ft): Water level as reported by transducer/datalogger (this is the depth of water above the transducer).
17. TIME: Time the discharge rate check was begun (addition or removal of water method). Note whether 12- or 24-hour clock was used.
18. FLOW METER (Addition or removal of water method): The amount of water added or removed as registered by the flowmeter, in gal of liters.
19. DISCHARGE RATE: Flowmeter reading divided by time interval (gal/min or liters/min).

20. SIGNATURE: The person completing this form must sign the form at the end of the test.

21. DATE: Date the form was signed.

3.5.2 Groundwater Levels – Single Well (Items on Figure SOP016-7)

1. CONTRACTOR: Organization performing the test.
2. SEQ. #: Enter page number of this set of forms (page # of #).
3. PROJECT NO.: Record the contractor assigned project number or the contract number.
4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.
5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.
6. LOCATION: Specific location.
7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.
8. CLIENT: Agency with the contract under which the work is being performed.

Well Data

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.
10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.
11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.
12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").
13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: Remedial investigation wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019).
14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.

15. DATE: Date of each water level reading
16. TIME: Time of each water level reading. Note whether 12- or 24-hour clock was used.
17. ELAPSED TIME: Time since test was begun.
18. DEPTH TO WATER: Measured depth to the groundwater table.
19. WATER ELEVATION: Elevation of the top of the groundwater table (use datum listed above).
20. MEAS. METH.: Method used to measure the water level in the well (see abbreviation key at the bottom of the data sheet).
21. TAPE NO.: The unique identification number of the traceable standard tape used to calibrate the measuring device.
22. WELL STATUS: Condition of the well at the time of measuring (see abbreviation key at the bottom of the data sheet).
23. REMARKS: Any additional pertinent comments not specifically required above.
24. INITIALS: Initials of person completing this data entry.
25. ABBREVIATION KEYS: Self explanatory.
26. SIGNATURE: The person completing this form must sign the form at the end of the test.
27. DATE: Date the form was signed.

3.5.3 Groundwater Levels – Single Well (Items on Figure SOP016-8)

1. CONTRACTOR: Organization performing the test.
2. SEQ. #: Enter page number of this set of forms (page # of #).
3. PROJECT NO.: Record the contractor assigned project number or the contract number.
4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.
5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.
6. LOCATION: Specific location.

7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.
8. CLIENT: Agency with the contract under which the work is being performed.

WELL DATA

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.
10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.
11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.
12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").
13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: All Rhode Island wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019).
14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.
15. DATALOGGER: This section is record of pertinent datalogger information.
16. MANUFACTURER: Record the manufacturer/brand name as stated on the datalogger.
17. MODEL: Enter the model number of the datalogger.
18. S/N: Enter the serial number of this datalogger.
19. TAG PROGRAMMED IN LOGGER: What is the identifier used in the datalogger's program to indicate that this unit was used to record a given data set?
20. TRANSDUCER: This section is a listing of pertinent information about the transducer used.
21. MANUFACTURER: Record the manufacturer/brand name as stated on the transducer.
22. MODEL: Enter the model number of the transducer.
23. S/N: Enter the serial number of this transducer.

24. INPUT/UNITS: What are the units this transducer uses?

25. RANGE: Record the pressure or depth range over which this transducer is certified.

CALIBRATION

26. PRESSURE RATING: This is taken from the manufacturer's specifications for a given transducer. (Usually in psi, or kpa).

27. "SUBMERGENCE = ___ (V) / (MV)": Record the voltage returned by the transducer at a given depth of submergence. Indicate whether the reading is in volts (v), or millivolts (mv).

28. VOLUME WATER ADDED/REMOVED: (Applicable if inert object insertion/removal method was not employed.) Record the volume of water added to or removed from the well.

29. DISCHARGE RATE: If z (above) is filled, enter the rate at which this water was added or removed.

30. INITIAL WATER LEVEL (ft): Enter the water level in the well at the beginning of the test.

31. PRESSURE TRANSDUCER SUBMERGENCE: Record the depth to which the transducer is submerged at the beginning of the test and the depth to the transducer at the end of the test. All depths will be recorded to the nearest 0.01 ft.

32. TIME: Record the time the test is begun and ended. Note whether 12- or 24-hour clock was used.

33. OBSERVED CHANGES IN ADJACENT WELLS: Note any changes in water levels in nearby wells.

34. RESULTS RECORDED ON DISKETTE #: Tracking number of the diskette on which these data are archived.

35. DISKETTE FILE NAME: Name of the file(s).

36. SIGNATURE: The person completing this form must sign the form at the end of the test

37. DATE: Date the form was signed.

3.6 GROUNDWATER LEVELS – MULTIPLE WELLS (Items on Figure SOP016-9)

1. CONTRACTOR: Organization performing the test.
2. SEQ. #: Enter page number of this set of forms (page # of #).
3. PROJECT NO.: Record the contractor assigned project number or the contract number.
4. PROJECT NAME: Record the name assigned by the contractor's organization to the project.
5. LOCATION: Specific location.
6. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.
7. CLIENT: Agency with the contract under which the work is being performed.
8. REMARKS: Any pertinent observations not specifically required above.
9. WELL: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.
10. DATE: Date this measurement was made.
11. TIME: Time this measurement was made. Note whether 12- or 24-hour clock was used.
12. DEPTH TO WATER: Depth from MP to top of groundwater table.
13. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.
14. MP ELEV.: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.
15. MEAS. METH.: Method used to measure the water level in the well (see abbreviation key at the bottom of the data sheet).
16. REMARKS/MP: Describe the location and nature of the measuring point.
17. INITIALS: Initials of the person completing this form.
18. ABBREVIATION KEYS: Self explanatory.

19. SIGNATURE: The person completing this form must sign the form at the end of the test.

20. DATE: Date the form was signed.

3.7 GROUNDWATER LEVELS – DATALOGGERS (Items on Figure SOP016-10)

1. CONTRACTOR: Organization performing the test.
2. SEQ. #: Enter page number of this set of forms (page # of #).
3. PROJECT NO.: Record the contractor assigned project number or the contract number.
4. WELL #: Record the well number as it appears on the well completion tag, affixed to the protector casing or well completion records.
5. PROJECT NAME: Record the name assigned by the contractor's organization to the project.
6. LOCATION: Specific location.
7. FIELD PARTY CHIEF: Printed name of the person responsible for this particular field test.
8. CLIENT: Agency with the contract under which the work is being performed.

WELL DATA

9. STICKUP: Enter the length of well casing extending above the average ground surface at the base of the protective casing.
10. MEASURED UP(+)/DOWN(-) FROM: Describe the starting point for the previous measurement.
11. MP ELEVATION: Enter the elevation of the measuring point here. NOTE: This datum may require reference to tables and/or maps and may be added after completing the day's field work.
12. DATUM = MSL OR: Is the datum for the previous elevation Mean Sea Level? If not, what? Also tell whether it was derived from a map elevation (write "MAP") or survey data (write "SURVEY").
13. MEASURING POINT DESCRIPTION: Describe the point used as the origin for all down-hole (water table) measurements. NOTE: All Rhode Island wells are required to have a permanently marked reference (measuring) point (refer to SOP No. 019, Section 3.4).
14. REMARKS: Record any pertinent observations about the site/well conditions not specifically required in the preceding.

DATALOGGER (This section is a record of pertinent datalogger information)

- 15. MANUFACTURER: Record the manufacturer/brand name as stated on the datalogger.
- 16. MODEL: Enter the model number of the datalogger.
- 17. S/N: Enter the serial number of this datalogger.
- 18. TAG PROGRAMMED IN LOGGER: What is the identifier used in the datalogger's program to indicate that this unit was used to record a given data set?

TRANSDUCER (This section is a listing of pertinent information about the transducer used)

- 19. MANUFACTURER: Record the manufacturer/brand name as stated on the transducer.
- 20. MODEL: Enter the model number of the transducer.
- 21. S/N: Enter the serial number of this transducer.
- 22. INPUT/UNITS: What are the units this transducer uses?
- 23. RANGE: Record the pressure or depth range over which this transducer is certified.

CALIBRATION

- 24. PRESSURE RATING: This is taken from the manufacturer's specifications for a given transducer (usually in psi, or kpa).
- 25. "SUBMERGENCE = ____ (V) / (MV)": Record the voltage returned by the transducer at a given depth of submergence. Indicate whether the reading is in volts (v), or millivolts (mv).
- 26. DATE: Date of each water level reading
- 27. TIME: Time of each water level reading. Note whether 12- or 24-hour clock was used.
- 28. LOGGING TIME INTERVAL: Time since test was begun.
- 29. WL FEET BELOW MP: Measured depth to the groundwater table from measuring point.
- 30. SUBMERGENCE: Depth of water above the transducer.
- 31. MEAS.METHOD: What device/method was used to measure the water level.
- 32. TAPE NO.: Record the tape identification number.
- 33. TRANSDUCER MOVED?: Was the transducer moved since the last water level reading?

34. REMARKS: Any pertinent remarks not otherwise specified.

35. INITIALS:

DATA TRANSFER TO DISKETTE:

36. DATE: Date data were archived onto diskette.

37. TIME: Time stamp the computer assigns the data file.

38. FILE NAME: Name assigned the data file.

39. SOFTWARE USED FOR TRANSFER: Any special software, or computer operating system used to write the files to diskette. NOTE: If a “shareware” archiver which compresses files was used, and the archived file is not self-extracting, a copy of the unarchive program should be copied onto the diskette also.

40. OUTPUT FORMAT: What is the format of the output file? (DOS, UNIX, Binary, Compressed?)

41. INITIALS: Initials of the person who copied the data to diskette.

42. ABBREVIATION KEY: Self-explanatory.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

None.

6. REFERENCES

U.S. Environmental Protection Agency. 1984. User's Guide to the Contract Laboratory Program. July.

FIGURE SOP016-1
FIELD PARAMETER LOGBOOK
SOIL AND SEDIMENT SAMPLES

HIGH CONCENTRATION EXPECTED?	HIGH HAZARD?
------------------------------	--------------

INSTALLATION/SITE _____ AREA _____

INST CODE _____ FILE NAME _____

SITE TYPE _____ SITE ID _____

FIELD SAMPLE NUMBER _____

DATE (MM/DD/YY) / / TIME _____ AM PM SAMPLE PROG. _____

DEPTH (TOP) _____ DEPTH INTERVAL _____ UNIT _____

SAMPLING METHOD:

SPLIT SPOON AUGER SHELBY TUBE SCOOP OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS
-----	----------	------------------	-----	---------

TOTAL NUMBER OF CONTAINERS FOR SAMPLE _____

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION: _____

SAMPLE FORM _____ COLOR _____ ODOR _____

PID (HNu) _____ UNUSUAL FEATURES _____

WEATHER/TEMPERATURE _____

SAMPLER _____

HIGH CONCENTRATION EXPECTED?

HIGH HAZARD?

FIGURE SOP016-2
FIELD PARAMETER LOGBOOK
GROUNDWATER AND SURFACE WATER SAMPLES

INSTALLATION/SITE	AREA
INST CODE	FILE NAME
SITE ID	FIELD SAMPLE NUMBER
DATE (MM/DD/YY) / /	TIME AM PM
DEPTH (TOP)	DEPTH INTERVAL
	SAMPLE PROG. UNITS

SAMPLING MEASUREMENTS

CAL REF.	pH	TEMPERATURE C	CONDUCTIVITY	OTHER
----------	----	---------------	--------------	-------

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS
-----	----------	------------------	-----	---------

TOTAL NUMBER OF CONTAINERS FOR SAMPLE

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION

SAMPLING METHOD

SAMPLE FORM

COLOR

ODOR

PID (HNu)

UNUSUAL FEATURES

WEATHER/TEMPERATURE _____ SAMPLER _____

**FIGURE SOP016-3
MAP FILE LOGBOOK**

SITE ID _____ POINTER _____

DESCRIPTION/MEASUREMENTS

SKETCH/DIMENSIONS:

MAP REFERENCE

COORDINATE DEFINITION (X is _____ Y is _____)

COORDINATE SYSTEM _____ SOURCE _____ ACCURACY _____

X-COORDINATE _____ Y-COORDINATE _____ UNITS _____

ELEVATION REFERENCE

ELEVATION SOURCE _____ ACCURACY _____ ELEVATION _____

UNITS _____

SAMPLER

FIGURE SOP016-4
MAP FILE AND PURGING LOGBOOK
GROUNDWATER SAMPLES

WELL COORD. OR ID _____ SAMPLE NO. _____
 WELL/SITE _____
 DESCRIPTION _____

X-COORD. _____ Y-COORD. _____ ELEV. _____ UNITS _____
 DATE ____/____/____ TIME _____ AIR TEMP. _____

WELL DEPTH _____ ft _____ in. CASING HT. _____ ft _____ in.
 WATER DEPTH _____ ft _____ in. WELL DIAMETER _____ in.
 WATER COLUMN HEIGHT _____ ft _____ in. SANDPACK DIAM. _____ in.
 EQUIVALENT VOLUME OF STANDING WATER _____ (gal) (L)
 VOLUME OF BAILER _____ (gal) (L) or PUMP RATE _____ (gpm) (lpm)
 TOTAL NO. OF BAILERS (5 EV) _____ or PUMP TIME _____ MIN.
 WELL WENT DRY? [Yes] [No] NUM. OF BAILERS _____ or PUMP TIME _____ MIN
 VOL. REMOVED _____ (gal) (L) RECOVERY TIME _____ MIN
 PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED _____ (gal) (L)

Date and Time	Quantity Removed	Time Required	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/odor/partic.)
(before)									
(during)									
(during)									
(during)									
(after)									

COMMENTS: _____

SIGNATURE _____

FIGURE SOP016-5
FIELD CALIBRATION: pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY,
OXIDATION-REDUCTION POTENTIAL, AND DISSOLVED OXYGEN METERS

INITIAL CALIBRATION	FINAL CALIBRATION
DATE:	DATE:
TIME:	TIME:

pH METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

pH STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
7.0			
10.0			
4.0			

CONDUCTIVITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

COND. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

TEMPERATURE METER CALIBRATION

METER ID _____

TEMP. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
ICE WATER			
BOILING WATER			
OTHER			

FIGURE SOP016-5 (continued)**TURBIDITY METER CALIBRATION**

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

COMMENTS: _____

SIGNATURE _____

FIGURE SOP016-7
GROUNDWATER LEVELS – SINGLE WELL

Contractor: _____ **Seq. #** /

Project No.:
Project Name:
Field Party Chief:

WELL DATA:

Stickup: _____ (ft)
MP Elevation:
Area:

Datum = MSL or:

Measuring Point Description:

Datalogger:

Manufacturer: _____ Model: _____ S/N: _____
Tag No. Programmed in Logger:

Transducer: Manufacturer: _____ Model: _____ S/N: _____
Input/Units: _____ Range: _____

Calibration:

Pressure Rating:
0 ft submergence = _____ (v) / (mv) ft submergence = _____ (v) / (mv)

Volume Water Added/Removed:
Discharge Rate:
Initial Water Level (ft):

Pressure Transducer Submergence

Initial (ft): _____ Final(ft): _____ Time:Start: _____ End: _____
Observed Changes in Adjacent Wells:

Results Recorded on Diskette #:
Diskette File Name:

Signature: _____ **Date:** _____

Seq. # /

Field Party Chief:

Stickup: (ft)
MP Elevation:

Datum = MSL or:

[illegible]

A = Airline
C = Chalk and tape
E = Electric tape
T = Tape with popper
X = Other (describe in remarks)

D = Dry
F = Flowing
P = Pumping
RP = Recently pumped
NP = Nearby well pumping
NRP = Nearby well recently
X = Obstructed

Signature: _____ **Date:** _____

Client:

[illegible]

X = Obstructed

FIGURE SOP016-9 GROUNDWATER LEVELS DATALOGGERS

Contractor

Project No.:

Project Name:

Field Party Chief:

Well No.:**Site:****Area:**

WELL DATA: Stickup: (ft) up (+)/down (-) from:

Measuring Point Description:

Remarks:

Datalogger:

Manufacturer:

Model:

S/N:

Tag No. Programmed in Logger:

Transducer: Manufacturer:

Model:

S/N:

Input/Units:

Range:

Calibration: Pressure Rating:

0 ft submergence = (v) / (mv)

ft submergence = (v)

Logging	Date	Time	Logging Time Interval	WL, ft Below MP	Submergence (logger reading)	Meas. Method	Tape No.	Well Status	Transducer Moved	Remarks	Initials
Start											
Stop											
Start											
Stop											

Data Transfer to Disk

Date	Time	File Name	Software Used for Transfer	Output Format	Initials

Measurement Method:

A = Airline

C = Chalk and tape

E = Electric tape

T = Tape with popper

X = Other (describe in remarks)

Well Status:

D = Dry

F = Flowing

P = Pumping

RP = Recently

NP = Nearby well pumping

NRP = Nearby well recently pumped

X = Obstructed

Signature**Date**



Standard Operating Procedure No. 019 for Monitoring Well Installation

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Revision 0
August 2007

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1. SCOPE AND APPLICATION

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this Standard Operating Procedure is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. The applicable Work Plan should be consulted for specific installation instructions. The term “monitoring wells,” as used herein, is defined to denote any environmental sampling well. An example well log form is provided in Appendix A. Alternate, equivalent forms are acceptable.

2. MATERIALS

2.1 DRILLING EQUIPMENT

The following drilling equipment may be required:

- Appropriately sized drill adequately equipped with augers, bits, drill stem, etc.
- Steam cleaner and water obtained from approved source for decontaminating drilling equipment.
- Photoionization Detector: Microtip HL-200 (or equivalent)
- Water level indicator
- Weighted steel tape measure
- Lower explosive limit – oxygen monitor
- Steel drums for intrusion derived wastes (drill cuttings, contaminated personal protective equipment, decontamination solutions, etc.)
- Source of approved water
- Heavy plastic sheeting
- Sorbent pads and/or log.

2.2 WELL INSTALLATION MATERIALS¹

The following well installation materials may be required:

- Well screen:²
 - Polyvinyl chloride (PVC): JOHNSON (or equivalent); PVC 0.010 slot; Schedule 40; flush-threaded (leak-proof) joints; PVC complies with American Society for Testing and Materials (ASTM) D2665, ASTM D1784, and ASTM F480; free of ink markings; cleaned and prepackaged by manufacturer.
 - Stainless steel: JOHNSON (or equivalent); stainless steel 0.010 slot; 304 stainless steel³; ASTM F480 flush threads; cleaned, wrapped, and heat sealed by manufacturer.
- Riser pipe:
 - PVC: JOHNSON (or equivalent); STD; PVC; Schedule 40; flush-threaded (leak-proof) joints; PVC complies with ASTM D2665, ASTM D1784, and ASTM F480; free of ink markings; cleaned and prepackaged by manufacturer.
 - Stainless steel: JOHNSON (or equivalent); Schedule 5; 304 stainless steel; ASTM Type A312 material; 4-in. diameter; cleaned, wrapped, and heat sealed by manufacturer.
- Plugs/caps: JOHNSON (or equivalent); standard PVC or stainless steel.
- Filter pack: MORIE, 100 well gravel (or equivalent). NOTE: Final gradation may vary as a function of the gradation of the formation.²
- Fine Ottawa sand.
- Bentonite seal: BAROID, bentonite pellets (3/8-in. diameter)
- Cement: Type II Portland Cement (table below).

-
1. Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack, bentonite powder, and bentonite pellets will be supplied to the Project Manager.
 2. Well screen slot size and filter pack gradation will be determined from sieve analysis of aquifer materials. Screen and casing material type will be determined based on field tests of groundwater chemistry and contaminants.
 3. Unless the sum of Cl-, F-, and Br- is >1,000 ppm, in which case Type 316 should be used.

Cement Type	Special Characteristics	Recommended Usage
I	No special properties	General use as grout mix or cement plug (if sulfates <250 ppm), surface pad.
IA	Air-entraining Type I (Note that air entrainment properties can be achieved by chemical admixtures)	Air entrainment gives cement greater freeze-thaw resistance. Recommended for surface pads.
II	Moderate sulfate resistance, low heat of hydration	General use as grout mix or cement plug where groundwater sulfate >250 ppm and <1,500 ppm, surface pad.
IIA	Air-entraining Type II	See Type IA.
III	High early strength, high heat of hydration	Elevated temperature can damage well casing and fracture grout/cement plugs. NOT RECOMMENDED.
IIIA	Air-entraining Type III	NOT RECOMMENDED.
IV	Low heat of hydration	General use as grout mix or cement plug preferred type for well abandonment to ensure intact grout/cement plug.
V	High Sulfate resistance	Use when groundwater sulfate levels >1,500 ppm.

- Bentonite powder: BAROID, Aquagel Gold Seal.
- Steel protective casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted.⁴
- Geotextile: MIRAFI (or equivalent); GTF 130; non-woven; 4 oz.
- Coarse (blanket) gravel: Crushed stone aggregate.
- Containers for purged water, as required.
- Submersible pump or bailer of appropriate capacity, and surge block sized to fit well.
- Hach DREL 2000 portable laboratory (or equivalent).
- Conductivity, pH, oxidation-reduction potential (ORP), turbidity, dissolved oxygen, and temperature meters.
- Electric well sounder and measuring tape.
- Portland Type II cement (see previous table).
- Steel Posts (pickets), painted (see footnote).

4. All painted components (protector casing, steel pickets) will be painted high-visibility orange and allowed to dry completely prior to being brought onsite.

2.3 DOCUMENTATION

The following document may be provided:

- Copy of appropriate Work Plan
- Copy of approved Health and Safety Plan
- Copies of well and excavation permits
- Boring log forms
- Well completion diagram form
- Well development form.

2.4 GEOLOGIST'S PERSONAL EQUIPMENT

The following equipment may be required for the geologist:

- 10X handlens
- Unified Soil classification System chart
- Munsell color chart
- Sieve set (Keck model SS-81 or equivalent)
- Personal protective equipment as required by the Health and Safety Plan.

3. PROCEDURE

3.1 MATERIALS APPROVAL

Water sources for drilling, grouting, sealing, filter placement, well installation, and equipment decontamination must be approved by the Project Manager prior to arrival of the drilling equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analyses over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the Project Manager prior to the arrival of the drilling equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product.

Granular Filter Pack material must be approved by the Project Manager prior to drilling. A 1-pint representative sample must be supplied to the Project Manager. Information required includes: lithology, grain size distribution, brand name, source, processing method, and slot size of intended screen.

Portland Type II cement will be used for grout (see previous table).

3.2 DRILLING

The objective of the selected drilling technique is to ensure that the drilling method provides representative data while minimizing subsurface contamination, cross-contamination of aquifers, and drilling costs. The preferred drilling method is with a hollow-stem auger. Other drilling methods⁵ are approved as conditions warrant, and will not require variances be issued by the U.S. Environmental Protection Agency. The method used at a specific site will be proposed in the work plan and evaluated by the Project Manager. Any drilling method not listed herein will require approval on a case by case basis by the U.S. Environmental Protection Agency.

A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities into the monitoring well logbook. The Site Geologist will be responsible at only one operating rig for the logging of samples, monitoring of drilling operations, recording of water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures of the rig. The Site Geologist will have onsite sufficient equipment in operable condition to perform efficiently his/her duties as outlined in the contractual documents. Items in the possession of each Site Geologist will include the approved Health and Safety Plan, this Standard Operating Procedure, a hand lens (10X), a standard color chart, grain-size chart, and a weighted (with steel or iron) steel tape long enough to measure the deepest well, heavy enough to reach that depth, and small enough to fit readily within the annulus between the well and drill casing. The Site Geologist will also have onsite, a water level measuring device, preferably electrical.

Only solid vegetable shortening (e.g., Crisco[®]) without flavoring or additives may be used on downhole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, and field equipment/vehicles.

-
5. If the design depth of the well is <100 ft, open, hollow-stem augers will be used to drill the well unless “running sands” preclude the use of open augers. In that case, an inert “knockout” plug may be used in the bottom of the auger string. This plug will be driven out of the augers and left at the bottom of the hole when the well is installed.

If the design depth of the well is >100 ft, rotary drilling methods may be used to install wells. The following drill fluids and methods are approved in the order listed: (1) rotary drilling with water from an approved source as drilling fluid (clays from the formations will tend thicken the fluid and coat the walls of the borehole and this is acceptable); (2) rotary drilling with water as a fluid, advancing a temporary casing with the bit to maintain an open hole; and (3) mud rotary using water with additives as drill fluid. Due to the potential for aquifer contamination and plugging, mud rotary drilling is not recommended for monitoring wells. If, however, “running sands” are encountered and the aquifer is expected to have a relatively high flow rate, then mud rotary is considered an approved method. Pure sodium bentonite is the only approved additive. Mud rotary drilling must be halted at the last aquitard above the target aquifer. Casing must be set, all bentonite-bearing fluids flushed from the hole and drill rig, and drilling may be resumed using water only as the drill fluid until the target depth is reached.

Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in areas in contact with drilling fluid. The ground surface at the well site will be protected from possible coolant, fuel, and hydraulic fluid spills and/or leakage by placement of plastic sheeting with raised edges, draining into a lined catch basin large enough to contain spills and/or leakage from motors, radiators, or vehicle tanks. Sorbent pillows will be placed to catch obvious leaks from the drill rig. Sorbent logs may be used instead of, or in conjunction with, a lined catch basin to contain spills.

An accurate measurement of the water level will be made upon encountering water in the borehole and later upon stabilization. Levels will be periodically checked throughout the course of drilling. Any unusual change in the water level in the hole, such as a sudden rise of a few inches may indicate artesian pressure in a confined aquifer, will be the basis for cessation of drilling. The geologist will immediately contact the Project Manager⁶. Particular attention for such water level changes will be given after penetrating any clay or silt bed, regardless of thickness, which has the potential to act as a confining layer.

Anticipated depths of wells are given in well specific work plans. In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with the Project Manager. The current boring conditions (depth, nature of the stratigraphic unit, and water table depth) will be compared to those of other wells nearby to decide to continue drilling or to terminate and complete the well.

If the well is to be installed in the surficial aquifer, drilling will be terminated before penetrating the basal aquitard. The basal aquitard is defined as the first 2 ft-thick clay below the water table, or below 5 ft in the case of a shallow aquifer.

If the well is to be installed in a lower, confined aquifer:

- Penetrations of aquifers located lower than the water table aquifer will be limited to avoid cross-contamination.
- Placement of new upper confined aquifer wells will be initially limited to those areas where contamination has been confirmed.
- The location of upper confined aquifer wells will be based upon the findings of the water table aquifer investigation. Areas of known contamination will be targeted for installing upper confined aquifer wells for the purposes of delineating vertical contamination.

6. The contract technical oversight will also be contacted for guidance.

- Where possible, upper-confined aquifer wells will be located such that they afford triangulation with other wells within the same aquifer to allow for a determination of groundwater flow direction.
- Some upper-confined aquifer wells will be installed approximately 10-15 ft from water table wells to enable the accurate assessment of vertical hydraulic gradients. If the direction of groundwater flow is known, wells within a group will be located sidegradient of each other.
- The boring will be advanced until the base of the surficial aquifer is reached (Section 3.2).
- An outer, surface casing will be set 2-5 ft into the confining layer to minimize the potential for cross-contamination from the unconfined aquifer during drilling activities.
- The surface casing will be driven into the confining bed and grouted into place. Grout will be tremied into the annulus around the outside of the casing to within 5 ft of the ground surface. A grout plug at least 2 ft thick will be tremied into the bottom of the surface casing. The grout will be permitted to cure for 24 hours. All drilling fluids within the surface casing will then be removed, and the casing will be flushed with clean potable water.
- The drilling equipment will be decontaminated, a smaller bit or auger selected, and the hole will be continued through the grout plug into the confined aquifer.
- If deeper aquifers are to be screened, repeat preceding steps until total depth is reached.

If dense non-aqueous phase liquid (DNAPL) contamination is detected during drilling, the well will be terminated and completed at the base of the aquifer. Drilling will not continue through the confining unit.

Stainless steel screens will be used in DNAPL wells. Screen size selection will be according to criteria set forth in Section 3.4. The formation grain size will be multiplied by the higher factor (6) to determine filter pack grain size. This will ensure that the filter pack is sufficiently coarse to permit DNAPL to pass freely from the formation into the coarser filter pack, then into the open well (Cohen and Mercer 1993).

DNAPL sampling cups are prohibited. The well screen will be capped, and set 0.3 ft (0.5 ft max.) into the top of the confining bed and rest on the bottom of the hole or bentonite backfill (if used). No sand will be placed below the screen. The remainder of the well installation and completion will be accomplished according to Section 3.4.

3.3 LOGGING

All borings for monitoring wells will be logged by a geologist. Logs will be recorded in a field logbook and/or a boring log. If the information is recorded in a logbook, it will be transferred to Boring Log Forms on a daily basis. Field notes are to include, as a minimum:

- Boring number
- Material description (as discussed below)
- Weather conditions
- Evidence of contamination
- Water conditions (including measured water levels)
- Daily drilling footage and quantities (for billing purposes)
- Notations on man-placed materials
- Drilling method and borehole diameter
- Any deviations from established field plans
- Blow counts for standard penetration tests
- Core and split-spoon recoveries.

Material description for soil samples must include:

- Classification
- Unified Soil Classification symbol
- Secondary components and estimated percentages
- Color
- Plasticity
- Consistency
- Density
- Moisture content
- Texture/fabric/bedding and orientation
- Grain angularity
- Depositional environment and formation
- Incidental odors
- Photoionization detector reading(s)
- Staining.

Material description for rock samples must include:

- Classification
- Lithologic characteristics
- Bedding/banding characteristics
- Color
- Hardness
- Degree of cementation
- Texture
- Structure and orientation

- Degree of weathering
- Solution or void conditions
- Primary and secondary permeability
- Sample recovery
- Incidental odors
- Photoionization detector reading(s)
- Staining.

3.4 WELL CONSTRUCTION AND INSTALLATION

After the hole is drilled and logged, backfill hole as required for proper screen placement. The integrity of the aquitard will be restored by placing a bentonite plug of an appropriate thickness, either to the top of the aquitard (normal well installation) or to within 0.3 ft of the top of the aquitard (DNAPL well). Aquifer fill will be clean filter pack.

Normal screen placement for the water table (surficial) aquifer will be within 2 ft of the screen extending above the static water level. The bottom of the screen will rest no more than 6 in. from the bottom of the hole or backfill material, whichever is applicable.

NOTE: The end cap in DNAPL wells will rest on the bottom of the bottom of the hole, or bentonite backfill if applicable (Section 3.2).

Screen placement for a confined aquifer well will normally be at the top of the confined aquifer.

Screen lengths will not normally exceed 10 ft. If it appears advantageous in a given situation (e.g., to screen an entire aquifer which is thicker than 10 ft), approval must be sought on a case-by-case basis from the appropriate regulatory agency. Otherwise, wells will be screened as follows:

Thickness of Aquifer	Action
<10 ft	Screen entire aquifer
>10 ft <30 ft	Screen top 10 ft consider vertically nested well cluster
>30 ft	Install vertically nested well cluster

The installation of monitoring wells in uncased or partially cased holes will begin within 12 hours of completion of drilling, or if the hole is to be logged, within 12 hours of well logging, and within 48 hours for holes fully cased with temporary drill casings. Once installation has begun, work will continue until the well has been grouted and the drill casing has been removed.

Well screens, casings, and fittings will conform to National Sanitation Foundation Standard 14 or ASTM equivalent for potable water usage. These materials will bear the appropriate rating logo. If the logos are not present, a written statement from the manufacturer/supplier stating that the materials contain the appropriate rating must be obtained. Material used will be new and essentially chemically inert to the site environment.

Well screen and casing should be inert with respect to the groundwater; therefore, the selection of screen and casing material will be based on select field tests of aquifer chemistry and potential contaminants. The screen will be capped without sediment trap or DNAPL sampling cup, and lowered into the hole. The well casing will be pre-cut to extend 2-2.5 ft above ground surface. Prior to placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

Screen slot size will be appropriately sized to retain 90-100 percent of the filter pack material, the size of which will be determined by sieve analysis of formational material (Section 3.4).

The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps may either be vented, or a telescopic fit, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case, it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

Filter pack material will be placed, lightly tamped, and leveled. Filter pack will extend from the bottom of the hole to a height of 1-2 ft above the top of the screen. The filter pack will be capped with a minimum of 1 ft of fine (Ottawa) sand to prevent the bentonite seal from infiltrating the filter pack. If the bentonite seal is placed as a slurry, a minimum of 2 ft of fine sand will be required.

If the hole is less than 20-ft deep, the filter pack may be poured into the annulus directly. If the hole is deeper than 20 ft, the filter pack must be tremied into place.

Granular filter packs will be chemically and texturally clean, inert, and siliceous.

Filter pack grain size will be based on formation grain-size analysis. The D30 (70 percent retained) sieve size multiplied by a factor of not less than 3 nor greater than 6 will be used to determine the appropriate grain size.

Calculations regarding filter pack volumes will be entered into the Field Logbook along with any discrepancies between calculated and actual volumes used. If a discrepancy of greater than 10 percent exists between calculated and actual volumes exists, an explanation for the discrepancy will also be entered in the Field Logbook.

Bentonite seals will be no less than 2-ft thick nor more than 5-ft thick as measured immediately after placement. The normal installation will include a 5-ft seal. Thinner seals may be used in special cases. The final depth to the top of the bentonite seal will be measured and recorded.

3.4.1 Grout

Grout used in construction will be composed by weight of:

- 20 parts cement (Portland cement, type II) (see previous table)
- 0.4-1 part (maximum) (2-5 percent) bentonite
- 8-gal (maximum) approved water per 94-lb bag of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump prior to placement. Grout placement will be performed using a commercially available grout pump and a rigid, side discharge tremie pipe.

The following will be noted in the Field Logbook: (1) calculations of predicted grout volumes; (2) exact amounts of cement, bentonite, and water used in mixing grout; (3) actual volume of grout placed in the hole; and (4) any discrepancies between calculated and actual volumes used. If a discrepancy of greater than 10 percent exists between calculated and actual volumes exists, an explanation for the discrepancy will also be entered in the Field Logbook.

Well protective casings will be installed around all monitoring wells on the following day as the initial grout placement around the well. Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

The construction of each well will be depicted as built in a well construction diagram. The diagram will be attached to the boring log and will graphically denote:

- Screen location, length
- Joint location
- Granular filter pack
- Seal
- Grout
- Cave-in
- Centralizers
- Height of riser
- Protective casing detail.

3.5 MONITORING WELL COMPLETION

Assemble appropriate decontaminated lengths of pipe and screen. Make sure these are clean and free of grease, soil, and residue. Lower each section of pipe and screen into the borehole, one at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethylene tape, or glue may be used in joining the pipe and screen sections.

If a well extends below 50 ft, centralizers will be installed at 50 ft and every 50 ft thereafter except within screened interval and bentonite seal. Centralizer material will be PVC, polytetrafluoroethylene, or stainless steel. Determination of centralizer material will be based on the same criteria as screen and casing selection.

Cut the riser with a pipe cutter approximately 2-2.5 ft above grade. All pipe cuts **MUST** be square to ensure that the elevation between the highest and lowest point of the well casing is less than or equal to 0.02 ft. Notch, file, or otherwise permanently scribe a permanent reference point on the top of the casing.

Torches and saws may not be used to cut the riser. Care must be taken that all filings or trimmings cut from the reference point fall outside the riser rather than into the well. **Under no circumstances will a permanent marker or paint pencil be used to mark the reference point.**

In some locations, safety requirements may mandate that a well be flush-mounted with no stick-up. If a flush-mounted well is required at a given location, an internal pressure cap must be used instead of a vented cap to ensure that rainwater cannot pool around the wellhead and enter the well through the cap.

When the well is set to the bottom of the hole, temporarily place a cap on top of the pipe to keep the well interior clean.

Place the appropriate filter pack (Section 3.4). Monitor the rise annulus with a weighted tape to assure that bridging is not occurring.

After the pack is in place, wait 3-5 minutes for the material to settle, tamp and level a capped PVC pipe, and check its depth with weighted steel tape.

Add a 1-2 ft cap of fine-grained (Ottawa) sand to prevent infiltration of the filter pack by overlying bentonite seal. See Section 3.4 for guidance on appropriate thickness of fine sand layer.

Install the bentonite seal (2- to 5-ft thick) by dropping bentonite pellets into the hole gradually. If the well is deeper than 30 ft, a tremie pipe will be used to place either bentonite pellets or slurry. Tamp and level pellets. If the well is 30 ft, tamp with a capped PVC pipe, if >30 ft, tamping may be accomplished with the weighted end of the tape. In either case, check the depth to the top of the seal with a weighted tape as above.

If the bentonite pellets are of poor quality, they may have a tendency to hydrate and swell inside the tremie pipe and bridge. This situation may be solved by the following procedure:

1. Use a different brand of pellets. Different brands may have longer hydration times.

2. Freeze the pellets⁷. Note that this will require a longer wait time to allow proper hydration after the pellets thaw.
3. Place the bentonite seal as a slurry using a side-discharge tremie pipe as though installing grout. Note (Section 3.4) this will require that a minimum of 2 ft of fine sand be placed as a cap on top of the filter pack material.

Wait for the pellets to hydrate and swell. Hydration times will be determined by field test or by manufacturer's instructions. Normally this will be 30-60 minutes. Document the hydration time in the field notebook. If the pellets are above the water level in the hole, add several buckets of clean water to the boring. Document the amount of water added to the hole.

Mix an appropriate cement-bentonite slurry (Section 3.4). Be sure the mixture is thoroughly mixed and as thick as is practicable.

Lower a side discharge tremie pipe into the annulus to the level of the pellet seal.

Pump the grout slurry into the annulus while withdrawing the tremie pipe and temporary casing.

Stop the grout fill at 5 ft below the ground surface. Allow to cure for not less than 12 hours. If grout settles more than 6 in., add grout to bring level back up to within 5 ft of ground surface. Place approximately 2 ft of bentonite pellets (minimum 0.5 ft) in annulus. Seat the protective casing in the bentonite seal, allowing no more than 0.2 ft between the top of the well casing and the bottom of the protective casing cap. Fill inner annulus (between well casing and protective casing) with bentonite pellets to the level of the ground surface. Cover bentonite pellets with 1 ft of clean granular material (coarse sand or pea gravel filter pack). Fill the outer annulus (between the protective casing and the borehole) with neat cement. Allow the cement to mound above ground level and finish to slope away from the casing. Lock the cap.

— **OR** —

Continue the grout fill to the ground surface. Seat the protective casing in the grout, allowing no more than 0.2 ft between the top of the well casing and the bottom of the protective casing cap. Lock the cap.

— **AND** —

Allow the grout slurry to set overnight.

7. Bentonite pellets may be "flash-frozen" by brief immersion in liquid nitrogen (LN2). This can be accomplished by pouring LN2 over a small quantity (0.25-0.5 bucket) of pellets, allowing the LN2 to boil off, then pouring the pellets into the tremie pipe. **NOTE:** Use of LN2 is an additional jobsite hazard and must be addressed in the contractor's Health and Safety Plan. This contingency must be covered before drilling starts in order to avoid delays in well installation.

Fill the outer annulus (between the casing and the borehole) with neat cement. Allow the cement to mound above ground level and finish to slope away from the casing.

Slope the ground surface away from the casing for a distance of 2 ft, at a rate of no less than 1 in. in 2 ft. Surface this sloping pad with a geotextile mat covered by 3 in. of coarse gravel.

— OR —

Frame and pour a 4-ft square \times 6-in. thick (4 ft \times 4 ft \times 6 in.) concrete pad centered around the protective casing.

— AND —

Set pre-painted protective steel pickets (3 or 4) evenly around and 4 ft out from well. These pickets will be set into 2 ft deep holes, the holes will then be filled with concrete; and if the pickets are not capped, they will also be filled with concrete.

3.6 WELL DEVELOPMENT

Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well have been removed while restoring the aquifer hydraulic conductivity. Development corrects any damage to or clogging of the aquifer caused by drilling, increases the porosity of the aquifer in the vicinity of the well, and stabilizes the formation and filter pack sands around the well screen.

Well development will be initiated after 48 consecutive hours but no longer than 7 calendar days following grouting and/or placement of surface protection.

Two well development techniques, over pumping and surging, will be employed in tandem. Over pumping is simply pumping the well at a rate higher than recharge. Surging is the operation of a plunger up and down within the well casing similar to a piston in a cylinder.

3.6.1 Materials Required

The following materials will be required for well development:

- Well Development Form
- Boring Log and Well Completion Diagram for the well
- Submersible pump or bailer of appropriate capacity, and surge block
- Conductivity, pH, ORP, turbidity, dissolved oxygen, and temperature meters
- Electric well sounder and measuring tape
- Containers for purged water, if required.

3.6.2 Summary of Procedures and Data Requirements

Pump or bail the well to ensure that water flows into it, and to remove some of the fine materials from the well. Removal of a minimum of one equivalent volume is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately half its original level. If well recharge exceeds 15 gpm, the requirement to lower the head will be waived.

Slowly lower a close-fitting surge block into the well until it rests below the static water level, but above the screened interval. (NOTE: This latter is not required in the case of a light non-aqueous phase liquid well.)

Begin a gentle surging motion which will allow any material blocking the screen to break up, go into suspension, and move into the well. Continue surging for 5-10 minutes, remove surge block, and pump or bail the well, rapidly removing at least one equivalent volume.

Repeat previous step at successively lower levels within the well screen until the bottom of the well is reached. Note that development should always begin above, or at the top of, the screen and move progressively downward to prevent the surge block from becoming sand locked in the well casing. As development progresses, successive surging can be more vigorous and of longer duration as long as the amount of sediment in the screen is kept to a minimum.

Development is expected to take at least 2 hours in a small well installed in a clean sand, and may last several days in large wells, or in wells set in silts with low permeabilities.

Development will continue until little or no sediment can be pulled into the well, and target values for parameters listed below are met.

At a minimum, development will remove 3-5 well volumes of water. One development volume (DV) is defined as (1) equivalent volume, plus (1) the amount of fluid lost during drilling, plus (1) the volume of water used in filter pack placement.

1. Monitor water quality parameters before beginning development procedures, and after removing 2, 2.5, and 3 well volumes of water.
2. If these parameters have stabilized over the three readings, the well will be considered developed.
3. If the parameters have not stabilized after these three readings, continue pumping the well to develop, but stop surging. Monitor the stabilization parameters every half DV.
4. When the parameters have stabilized over three consecutive readings at half DV intervals, the well will be considered developed.

All water removed must be disposed of as directed by the Work Plan.

Record all data as required on a Well Development Record Form (Appendix A), which is made a part of the complete Well Record. These data include:

- Depths and dimensions of the well, casing, and screen obtained from the well diagram.
- Water losses and uses during drilling, obtained from the boring log for the well.
- Measurements of the following indicator parameters: turbidity, pH, conductivity, ORP potential, dissolved oxygen, and temperature.
- Target values for the indicator parameters listed above are as follows: pH – stabilize, conductivity – stabilize, ORP – stabilize, dissolved oxygen – stabilize, temperature – stabilize, turbidity – 5 nephelometric turbidity units or stabilize. A value is considered to have stabilized when three consecutive readings taken at half DV intervals are within 10 percent of each other.
- Notes on characteristics of the development water.
- Data on the equipment and technique used for development.
- Estimated recharge rate and rate/quantity of water removal during development.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Refer to the site-specific Health and Safety Plan for discussion of hazards and preventive measures during well development activities.

6. REFERENCES

Aller, L. et al. 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells, National Water Well Association.

American Society for Testing and Materials (ASTM). D2487-92 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).

ASTM. D5092-90 Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers.

Cohen, R.M. and J.W. Mercer. 1993. DNAPL Site Evaluation, CRC Press, Inc.

Nielsen, D.M. 1993. Correct Well Design Improves Monitoring, in *Environmental Protection*, Vol.4, No.7. July.

U.S. Army Toxic and Hazardous Materials Agency. 1987. Geotechnical Requirements for Drilling, Monitoring Wells, Data Acquisition and Reports. March.

U.S. Environmental Protection Agency. 1989. Groundwater Handbook.

Appendix A

Field Record of Well Development Form



FIELD RECORD OF WELL DEVELOPMENT

Project Name:	Project No:	Date:
EA Personnel:	Development Method:	
Weather/Temperature/Barometric Pressure:		Time:

Well No.:	Well Condition:
Well Diameter:	Measurement Reference:
Well Volume Calculations	
A. Depth To Water (ft):	D. Well Volume/ft:
B. Total Well Depth (ft):	E. Total Well Volume (gal)[C*D]:
C. Water Column Height (ft):	F. Five Well Volumes (gal):

Parameter	Beginning	1 Volume	2 Volumes	3 Volumes	4 Volumes	5 Volumes
Time (min)						
Depth to Water (ft)						
Purge Rate (gpm)						
Volume Purged (gal)						
pH						
Temperature (°F)						
Conductivity (µmhos/cm)						
Dissolved Oxygen						
Turbidity (NTU)						
ORP (mV)						
Parameter	6 Volumes	7 Volumes	8 Volumes	9 Volumes	10 Volumes	End
Time (min)						
Depth to Water (ft)						
Purge Rate (gpm)						
Volume Purged (gal)						
pH						
Temperature (°F)						
Conductivity (µmhos/cm)						
Dissolved Oxygen						
Turbidity (NTU)						
ORP (mV)						

NOTE: NTU = Nephelometric turbidity unit.
ORP = Oxidation-reduction potential.

COMMENTS AND OBSERVATIONS: _____



FIELD RECORD OF WELL DEVELOPMENT

Project Name:	Project No:	Date:
EA Personnel:	Development Method:	
Weather/Temperature/Barometric Pressure:		Time:

Well No.:	Well Condition:
Well Diameter:	Measurement Reference:

Parameter	Beginning	1 Volume	2 Volumes	3 Volumes	4 Volumes	5 Volumes
Time (min)						
Depth to Water (ft)						
Purge Rate (gpm)						
Volume Purged (gal)						
pH						
Temperature (°F)						
Conductivity (µmhos/cm)						
Dissolved Oxygen						
Turbidity (NTU)						
ORP (mV)						

Parameter	6 Volumes	7 Volumes	8 Volumes	9 Volumes	10 Volumes	End
Time (min)						
Depth to Water (ft)						
Purge Rate (gpm)						
Volume Purged (gal)						
pH						
Temperature (°F)						
Conductivity (µmhos/cm)						
Dissolved Oxygen						
Turbidity (NTU)						
ORP (mV)						



Standard Operating Procedure No. 024 for Photoionization Detector (Microtip HL-200)

Prepared by

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August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for field operations with a photoionization detector (PID). PIDs use an ultraviolet emitting lamp designed to detect, measure, and display the total concentration of airborne ionizable gases and vapors. This information is used to determine control measures such as protection and action levels.

Use of brand names in this Standard Operating Procedure is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable standard operating procedure for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Battery back	Regulator
Calibration gas (100ppm Isobutylene)	Tedlar bag
PID (i.e., Microtip HL-200)	Tygon tubing

3. STARTUP/CALIBRATION PROCEDURE

The following describes startup and calibration procedures:

- Turn the instrument on by pressing the back of the power switch located on the handle of the Microtip.
- The message “Warming up now, please wait” will be displayed for up to 3 minutes. After normal display appears, the Microtip is ready for calibration.
- Fill a Tedlar bag with the desired calibration gas (usually 100 ppm isobutylene).
- Press SETUP button and select the desired Cal Memory using the arrow keys (normally set to 200 ppm). Press EXIT button to leave setup function.
- Press CAL button and expose Microtip to Zero Gas. (Usually clean outdoor air will be suitable. If any doubt exists as to the cleanliness of the background air, a commercial source of zero gas should be used.).
- The Microtip then asks for the Span Gas concentration. Enter the known span gas concentration and then connect the Tedlar bag containing the Span Gas.

NOTE: THE SPAN GAS CONCENTRATION IS DEPENDENT UPON BOTH THE CONCENTRATION OF THE SPAN GAS USED AND THE RATING OF THE ULTRAVIOLET LAMP IN THE MICROTIP AT TIME OF CALIBRATION. IF USING 100 ppm ISOBUTYLENE AND THE STANDARD 10.6 eV LAMP, THE SPAN GAS CONCENTRATION WILL BE 56 ppm.

- Press enter and the Microtip sets its sensitivity. Once the display reverts to normal, the Microtip is calibrated and ready for use. Remove the Span Gas from the inlet probe. The instrument should be calibrated at least once a day.

4. BATTERY CHARGING

The following is a summary of battery charging procedures:

- Ensure Microtip is off.
- Set the voltage selector switch on the bottom of the battery charger to the appropriate AC line voltage.
- Press the release button on the bottom of the Microtip and remove the battery pack by sliding it backwards.
- Plug charger into the battery pack and then into an AC outlet and allow the battery to charge for at least 8 hours.
- After charging, remove the charger, first from the outlet then from the battery pack, and slide the battery pack back onto the Microtip.

5. PRECAUTIONS

The following is a summary of precautions while using the Microtip:

- Microtip does not carry an Intrinsic Safety Rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.
- All calibration, maintenance, and servicing of this device, including battery charging, must be performed in a safe area away from hazardous locations.
- Do not open or mutilate battery cells.
- Do not defeat proper polarity orientation between the battery pack and battery charger.
- Substitution of components may affect safety rating.

6. REFERENCES

Microtip HL-200 User's Manual. February 1990.



Standard Operating Procedure No. 025 for Soil Sampling

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for sampling surface and subsurface soils. Soil samples give an indication of the area and depth of site contamination, so a representative sample is very important.

2. MATERIALS

The following materials may be required:

Bucket auger or push tube sampler	Split-spoon, Shelby tube, or core barrel sampler
Drill rig and associated equipment	Stainless steel bowl
Personal protective equipment as required by the Health and Safety Plan	Stainless steel spoon, trowel, knife, spatula (as needed)

3. PROCEDURE

3.1 SUBSURFACE SAMPLES

Don personal protective equipment. Collect split-spoon, core barrel, or Shelby Tube samples during drilling. Upon opening sampler, or extruding sample, immediately screen soil for volatile organic compounds using either a photoionization detector or flame ionization detector. If sampling for volatile organic compounds, determining the area of highest concentration, use a stainless steel knife, trowel, or laboratory spatula to peel and sample this area. Log the sample in the Field Logbook while it is still in the sampler. Peel and transfer the remaining sample in a decontaminated stainless steel bowl. Mix thoroughly with a decontaminated stainless steel spoon or trowel. Place the sample into the required number of sample jars. Preserve samples as required. Discard any remaining sample into the drums being used for collection of cuttings. Decon sampling implements. All borings will be abandoned.

NOTE: If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same, except that two split-spoon samples will be mixed together. The Field Logbook should clearly state that the samples have been composited, which samples were composited, and why the compositing was done.

Samples taken for geotechnical analysis will be undisturbed samples, collected using a thin-walled (Shelby tube) sampler.

3.2 SURFICIAL SOIL SAMPLES

Don personal protective equipment. Remove vegetative mat. Collect a sample from under the vegetative mat with a stainless steel trowel, push tube sampler, or bucket auger. If a representative sample is desired over the depth of a shallow hole or if several shallow samples are to be taken to represent an area, composite as follows:

- As each sample is collected, place a standard volume in a stainless steel bowl.
- After all samples from each hole or area are in the bucket, homogenize the sample thoroughly with a decontaminated stainless steel spoon or spatula.

If no compositing is to occur, place sample directly into the sample jars. Place the leftover soil in the auger borings and holes left by sampling. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas. Samples for volatile organic compounds will not be composited. A separate sample will be taken from a central location of the area being composited and transferred directly from the sampler to the sample container. Preserve samples as required. Decon sampling implements.

4. MAINTENANCE

Not applicable.

5. PRECAUTIONS

Refer to the Health and Safety Plan.

Soil samples will not include vegetative matter, rocks, or pebbles, unless the latter are part of the overall soil matrix.

6. REFERENCES

American Society for Testing and Materials (ASTM). Method D1586-84, Penetration Test and Split-Barrel Sampling of Soils.

ASTM. Method D1587-83, Thin Walled Sampling of Soils.

Department of the Army, Office of the Chief of Engineers. 1972. Engineer Manual 1110-2-1907 Soil Sampling. 31 March.



Standard Operating Procedure No. 028 for Well and Boring Abandonment

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to establish the protocols by which all wells and borings will be safely abandoned. The primary objective of well abandonment is to ensure that the abandoned well or boring does not provide a conduit for the vertical migration of contamination between aquifers.

2. MATERIALS

The following materials may be required:

Drill rig	Bentonite pellets (seal)
Filter pack material	Cement (Portland Type II)
Pure sodium bentonite with no additives (bentonite) powder (grout)	Approved water

3. PROCEDURE

The procedures used in boring abandonment will ideally accomplish two objectives: (1) protect aquifers from cross-contamination by sealing the borehole, and (2) restore the strata in the borehole to nearly original conditions by selective placement of fill material.

Any casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, grout will be placed from the bottom of the hole to within 3 ft of the ground surface, and allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site or cluster.

If the hole is within 10 ft of a monitoring well in the same aquifer, or a replacement well is to be installed within 10 ft of the well, any temporary casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, the hole will then be backfilled with filter pack material opposite sand strata and bentonite or grout opposite substantial (2 ft or thicker) clay and silt strata. Where sand as backfill approaches the ground surface, 2 ft of bentonite will be placed above the sand and a 3-ft concrete plug will be placed at the surface. Otherwise, backfill materials will be placed from the bottom of the hole to within 3 ft of the ground surface. These materials will be allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

If the well is not within 10 ft of another monitoring well, or if there are no substantial, continuous sand bodies, and no replacement well is planned within 10 ft of the original well location, then the hole may be grouted from the bottom to the top.

3.1 GROUT

Grout used in construction will be composed by weight of:

- 20 parts cement (Portland cement, Type II or V)
- 0.4-1 part (maximum) (2-5 percent) bentonite
- 8 gal (maximum) approved water per 94-lb bag of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump prior to placement.

Grout placement will be performed using a commercially available grout pump and a rigid tremie pipe removal and grouting will be accomplished in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This will be accomplished by placing a grout pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the top-most section, until grout flows from the boring at ground surface. Efforts will be made to grout incrementally as the temporary casing is removed.

After 24 hours, the abandoned drilling site will be checked for grout settlement. On that day, any settlement depression will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at the ground surface.

3.2 BORINGS

The term “Borings” as used in this Standard Operating Procedure applies to any drilled hole made during the course of a remedial investigation which is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted for any reason prior to reaching that depth, borings will be grouted and normally closed within 4 hours, or within 4 hours or completion of logging of completion of logging.

3.2.1 Shallow Borings not Penetrating Water Table

Shallow borings made for the collection of subsurface soil samples will be abandoned by backfilling the hole with cuttings from the hole, **if and only if the boring does not penetrate the water table**. Clean sand will be used to make up any volume not filled by the cuttings.

3.2.2 Borings Penetrating the Water Table

Shallow borings made for the collection of subsurface soil samples **which penetrate the water table** will be abandoned by grouting the hole from the bottom to the top.

3.2.3 Deep Stratigraphic Borings

Deep stratigraphic borings will normally be located in areas which, by virtue of the historical record, are presumed relatively uncontaminated. Therefore, these borings are usually over 100 ft from any sampling well locations. Any boring located within 10 ft of a proposed well location, or located directly upgradient or downgradient (on anticipated flow line) of a proposed well location, will be abandoned by placing clean sand in the aquifer intervals and bentonite or grout in aquitard intervals as described above. If the boring is over 10 ft from and/or not upgradient of a proposed well location, the boring will be completely filled with grout.

3.3 WELLS

The following procedure applies to wells aborted prior to completion and existing wells determined to be ineffective or otherwise in need of closure.

Prior to abandoning any developed well, the proper well licensing body will be provided written notification along with an abandonment plan for that well.

If the well is within 10 ft of another monitoring well in the same aquifer, or a replacement well is to be installed within 10 ft of the well, casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, the hole will then be backfilled with filter pack material opposite sand strata and bentonite or grout opposite substantial (2 ft or thicker) clay and silt strata. Where sand as backfill approaches the ground surface, 2 ft of bentonite will be placed above the sand and below the concrete plug near the surface. Backfill materials will be placed from the bottom of the hole to within 3 ft of the ground surface. These materials will be allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

If the well is not within 10 ft of another monitoring well, and is not to be replaced by another well within 10 ft of the original location, casing will be pulled, drilled out, or thoroughly pierced. Using tremie pipe, grout will be placed from the bottom of the hole to within 3 ft of the ground surface, and allowed to settle for 24 hours. The remainder of the hole will be filled with concrete. The surface of the concrete will be mounded, smoothed, and inscribed with "ABD," for abandoned, any assigned well or boring designation, and the date the hole was abandoned. All boring logs, samples, completion records, and abandonment procedures will be included in the records of work on the site cluster.

4. REPLACEMENT WELLS

Replacement wells (if any) will normally be offset at least 10 ft from any abandoned well in a presumed upgradient or crossgradient groundwater direction. Site-specific conditions may necessitate variation to this placement.

5. PRECAUTIONS

None.



Standard Operating Procedure No. 033 for Aquifer (Hydraulic) Testing

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to define various hydraulic test methods which may be used, to specify how these tests are to be performed, and to provide appropriate methodologies for data reduction and interpretation. This SOP assumes a high degree of technical competency on the part of the investigator, in that certain assumptions and interpretations must be made in the selection of the test and data analysis to achieve valid results.

Aquifer testing is a process performed on selected wells to characterize the **Hydraulic Conductivity, Transmissivity, and Storativity** of the aquifer into which those wells are installed. Aquifer tests fall into two broad categories: pumping tests and slug tests. Pumping tests and slug tests are relatively inexpensive when compared to the remedial investigation budget as a whole, but it should be noted that, as with many *in situ* tests, aquifer tests may yield non-unique solutions.

Pumping tests are typically performed on wells installed in highly permeable materials, confined aquifers, and in areas of little or no suspected contamination in the groundwater. The principle of pumping tests is to remove water from the aquifer at a sufficient rate and for a sufficiently long period of time to stress the aquifer and cause measurable drawdown in the pumped well and adjacent (10 to several hundreds of feet) observation well(s). The aquifer characteristics can then be calculated by substituting inter-well distances, drawdown and well discharge data into appropriate equations, employing curve matching techniques, or using computer programs to reduce the data.

- Advantages of performing pumping tests are: (1) they encompass large areas, (2) test results are more accurate, (3) they can resolve complex aquifer conditions (e.g., boundaries), (4) time periods and pump rates can be varied, and (5) pumping tests represent remedial actions.
- Disadvantages of pumping tests are: (1) large quantities of potentially contaminated water are generated, (2) the contaminant plume may be moved by the test, (3) they are very costly, and (4) the data produced are averages over large areas.

Single-Well Permeability Tests (Slug Tests) are conducted to determine the characteristics of an aquifer in materials whose conductivity is too low to perform a pumping test, or in aquifers which are highly contaminated. Slug tests consist of inserting and/or removing either a slug of inert material of known volume, or a “slug” of water of known volume. Either method will cause an instantaneous rise or fall and subsequent recovery of the water table within the aquifer.

- Advantages of slug tests are: (1) they provide location-specific data, (2) they are small-scale and unlikely to move the contaminant plume, (3) no contaminated water (other than decontaminated solutions) is generated, (4) they are low cost, therefore (5) high data density is feasible, and (6) they can be used as an aid in selecting an appropriate area to perform pumping test(s).

- Disadvantages of performing slug tests are: (1) they provide less precise estimates of parameters; (2) they may not yield values for storativity; (3) they cannot resolve complex geometries; and (4) since they are short-term tests, they cannot resolve long-term events.

2. MATERIALS

2.1 ALL TESTS

The following materials may be required for all tests:

Copy of the site Health and Safety Plan	Health and Safety monitoring equipment, and personal protective equipment as required by the Health and Safety Plan
Calculator	Portable computer ¹
Containers for investigation-derived materials	Program diskettes
Data diskettes	Stopwatches
Decontamination equipment and supplies	

2.2 PUMPING TESTS

The following materials may be required for pumping tests:

Generators (2), fuel, extension cords and/or other source of onsite electrical power	Stainless steel submersible pump with associated tubing, clamps, and wiring
Logbook	Steel register flowmeter or stopwatch and bucket, graduated cylinder, or rain gauge
Pump	Transducer or other water level indicator ¹
Recording barometer or other source of local barometric readings (e.g., local airport or National Weather Service recording station)	Type curves for curve-matching analyses
Semilogarithmic paper-arithmetic vertical scale and logarithmic horizontal scale, or log-log paper	

2.3 SLUG TESTS

The following materials may be required for slug tests:

- Although removal (or insertion) of larger volumes of water may increase the recovery time(s) of the aquifer to the point that use of electrical water level meters or steel tapes is feasible, piezometers and data loggers are preferred because they tend to provide more complete records with less maintenance and operator error.

Test Conducted with Inert Cylinder	
Transducer ²	Inert, negatively buoyant cylinder of known volume
Logbook and/or field data sheets (examples provided in SOP No. 016)	Type curves for curve-matching analyses
Semilogarithmic paper-arithmetic vertical scale and logarithmic horizontal scale	Slug device (solid stainless steel or a sealed polyvinyl chloride cylinder filled with sand or similar material)
Test Conducted with Input/Output of Water	
Teflon bailer with Teflon-coated stainless steel leader and rope or pump	
— OR —	
Stainless-steel submersible pump or centrifugal pump	Pump wiring
Teflon or polyethylene flexible piping	Steel register flowmeter
Generator and fuel or other onsite source of electricity	American Society for Testing and Materials (ASTM) Type II water
Stainless-steel hose clamps	
— AND —	
Logbook	Type curves for curve-matching analyses
Semilogarithmic paper	Approved water and/or containers for removed water as required in SOP No. 042
Transducer or other water level indicator ¹	

3. PROCEDURE

Regardless of the test method chosen, the following general procedures must be considered:

- All well intrusive equipment must be decontaminated prior to and after use.
- All water removed from the test wells is considered, and must be treated, as purge water.
- The accuracy of the reading(s) from pressure transducer (piezometer) and data logger output should be verified prior to beginning any test, periodically during the test, and immediately after the test by measuring the groundwater level with one of the aforementioned mechanical devices.
- All water level tapes and meters should be calibrated against one master tape which is traceable to the National Institute of Standards and Technology. This calibration should be recorded in the field logbook.
- Repeated measurements at any one well should be made using the same tape.

3.1 SELECTION OF TEST METHOD

Before beginning any aquifer test, the investigator should have a good conceptual model of the site's hydrogeologic condition. This is essential because of the assumptions made in each

2. Field portable computer and associated equipment are considered as optional. Access to a computer will be required to down-load dataloggers.

analysis method. If the site conditions do not correspond with the assumptions in a given model, the analysis will be invalid. The conceptual understanding of the hydrogeology of the site can be developed from driller's logs and/or borehole geophysical logs of the wells to be tested, or from previous reports on the hydrogeology of the area. Table SOP033-1 is a decision tree which can be used with this conceptual model to determine the appropriate test/analysis method(s) which may be used at a given site.

3.2 PUMPING TESTS

Pumping tests can be divided into two broad categories: (1) those in which the pumping (discharge) rate is kept constant, and (2) those in which the pumping rate varies over time. All water removed from pumping wells must be disposed of appropriately.

3.2.1 Constant Discharge

These methods require that the discharge or injection rate in the pumping well be kept constant. Of these, the Theis method is the most widely referenced and applied, and serves as the basis for the solution of other, more complex boundary condition problems. Both the Cooper & Jacob and the Jacob modifications to the Theis method recognize that if pumping times are long and/or the distances to control wells are small, the Theis solution will yield a straight line plot on semilogarithmic paper, thereby simplifying the Theis equation. The Thiem method, unlike the Theis/Modified Theis methods, assumes that steady-state (equilibrium) conditions can be achieved in a confined aquifer.

The Theis method is detailed in Section 5.1.1 and ASTM D4106, the modified Theis method in Section 5.1.2 and ASTM D4105, and the Thiem method in Section 5.1.3.

The preceding methods assume that the aquifer being tested is confined. If the aquifer is unconfined or semi-confined (leaky), the preceding methods are invalid. DeGlee developed an equation which assumes that the tested aquifer is either overlain or underlain by a continuous, leaky confining layer which has uniform properties, and that leakage from the aquitard is proportional to the hydraulic gradient across the aquitard. Hantush and Jacob derived the same equation. Hantush later observed that a simpler approximation is possible if the ratio of the distance to monitoring well/leakage across the aquitard is <0.05 . As in all preceding cases, radial flow is assumed. The Hantush-Jacob method assumes that no storage occurs in the aquitard. The DeGlee equation and Hantush approximation is provided in Section 5.3.2.

Both Neuman and Witherspoon, and Hantush have proposed methods that take into account storage in the aquitard. The Neuman/Witherspoon method is provided in Section 5.3.1.

3.2.1.1 Field Operations

1. Arrange for all nearby extraction wells and automatic pump controls to be inoperative during the test period.

2. Measure and record the distance(s) between observation well(s) and pumping well.

3. Install pressure transducers in the pumping well and each observation well; submerge the transducer in the well to a sufficient depth to provide effective performance. Well bottom sediment plugging of the transducer must be avoided.
4. Perform a two-point calibration of each device as part of the installation, cross-checking data with a calibrated manual tape measure. Note that water levels must be noted and recorded to the nearest 0.01 ft.
5. Start dataloggers at each well several days before the test to record background fluctuations in the groundwater table. It is recommended that one observation well be selected beyond the expected influence of the test to monitor these background water table fluctuations during the actual test.
6. Using either the field barometer or data from a local meteorological station (Section 2.2), record precipitation and barometric pressure before, during and after the test.
7. Calibrate pump, flowmeter, and any other field instruments such as pH meters, etc.
8. Suspend pump at mid-point of pumping well screen and record water level.
 - If the recharge rate of the well is not known, conduct a step-drawdown test (Section 3.2.3) to determine the sustainable yield for the constant discharge test.
 - If the previous step is performed, the aquifer must be allowed to recover prior to performing the constant discharge test. At a minimum, the recovery period between step-test and pump test must be equal to the duration of the step test.
 - Manually check and record the water levels in all test wells before conducting the step test, at the end of the step test, and at 4-hour intervals (minimum) during the recovery period; recording these values in the field logbook.
9. Program the datalogger data acquisition rate as follows:
 - If the only mode of data acquisition is a fixed rate, program the datalogger(s) to record water levels every 5 seconds.
 - If a logarithmic data acquisition rate is possible, use this option.
 - If the data acquisition rate is programmable on the data logger, record data at incrementally lengthening frequencies. The following table is provided as an example, the actual rates at which data are acquired at a given site should be determined based on prior field tests.

Time after Aquifer Test Begins	Frequency of Measurements
0-60 minutes	Every 5-10 seconds
61-65 minutes	Every 15 seconds
65-75 minutes	Every 30 seconds
75-120 minutes	Every 5 minutes
120-180 minutes	Every 10 minutes
180 minutes – end of test	Every 30 minutes

10. Collect a complete round of static water levels, verifying transducer readings with a tape or electric water level meter.
 11. Start data logger(s).
 12. Start pump at previously selected rate. Monitor flow rate using flowmeter or stopwatch and bucket (rain gauge, graduated cylinder, etc.) half-hourly. Record this flow rate and adjust as necessary. Minimize fluctuations in flow rate, especially during the early stages of the test.
 13. Periodically download data from the loggers and plot drawdown as a function of time to assess the status of the test in real time. Under no circumstances should the flow rate be varied during the test.³ If drawdown is either falling substantially above or below predicted levels, then a decision should be made to continue the test at that pumping rate, terminate the test, allow the aquifer to recover, or restart the test at a different pumping rate.
 14. Continue pumping and recording water levels for a total period of 72-96 hours (3-4 days). After the drawdown portion of the test, download the data onto data diskettes using the portable computer.
 15. Reprogram the dataloggers to record a reading every 5 seconds or a logarithmic or variable interval if available on the datalogger.
 16. Turn off the pump and allow the groundwater to recover to within 90 percent of static conditions. The pump should be equipped with a foot valve to prevent backflow of the column pipe fluid.
 17. Periodically download data from the logger and plot recovery as a function of time to assess the status of the test in real time.
-
3. After a period of at least 12 hours into the test, brief interruptions (less than 5 minutes) in pumping due to mechanical failure are acceptable without re-starting the test. All critical equipment should have onsite backups as a contingency against equipment failures. Inasmuch as refueling an onsite generator every 4-10 hours while it is running is considered an unsafe practice, two generators should be provided at the pumping well site to maintain power to the pump during the test.

18. After recovery to 90 percent of static conditions, remove the dataloggers, pressure transducers, and cables from all the observation wells. Download the data onto data diskettes using the portable computer.

19. Collect a complete round of water levels from all wells in the monitoring network.

3.2.2 Variable Discharge

Variable discharge methods have been presented by numerous researchers. These methods are performed as a series of constant-rate, stepped changes in discharge rate. These changes in discharge rate may be linear or exponential. Type curves are derived for control wells. These methods can be applied in extensive leaky aquifers, but are generally used in confined aquifers. The only requirement is that the response to a unit stress be known. The step-test is incorporated as a preliminary measure to determine the optimal sustainable discharge rate for a given aquifer (Section 3.2.1.1). Otherwise, variable discharge methods are included herein for the sake of completeness. They are not widely used outside the research environment for aquifer characterization. No further details on variable pump rate tests are provided in this SOP.

Install a variable speed submersible pump and a pressure transducer into the pumping well.

Install pressure transducers into the nearby (closest) observation wells to provide preliminary indications of expected drawdown during the constant-discharge test.

Allow water level(s) to stabilize to original water level after installing the pump and transducer(s).

Program a datalogger to collect readings at 5- to 10-second intervals. If logarithmic programming is available, this collection period may be expanded to 1-minute increments by the completion of each step, where upon 5- to 10-second intervals will again be required to coincide with the start of the next step.

Measure static water levels from all wells expected to be influenced by the test, and calibrate pressure transducers. Record this information in the field logbook and field data sheets.

Select the pumping rates for the step-test. Four 100-minute steps should be run at steadily increasing flow rates. The flow rates should be selected, based on a preliminary estimate of a sustainable rate (ESR) as follows:

Step	Duration (minutes)	Pumping Rate (%)
1	100	25
2	100	50
3	100	100
4	100	125

Program the dataloggers, calibrate the pump to the initial flow rate, and initiate the test at 25 percent ESR. At the completion of the first step, increase the pumping rate to 50 percent ESR as instantaneously as possible. The pump should not be shut off between steps. At the completion of the second step, increase the flow rate to 100 percent ESR as instantaneously as possible. At the completion of the third step, increase the flow rate to 125 percent ESR as instantaneously as possible. At the completion of the fourth step, shut off the pump and record the recovery of water levels to at least 90 percent of static conditions.

During the test, plot drawdown in the pumping well on both arithmetic and semi-logarithmic graph paper to assess the performance of the test in real time. Make any adjustments to the test as appropriate, i.e., the addition of a fifth step at a higher rate if the aquifer does not appear to be adequately stressed, or termination of the test if the well is drawn dry.

At the conclusion of the test, analyze the data and select a pumping rate for the constant-discharge test. This rate should be sustainable for the anticipated duration of the test, and place the maximum stress on the aquifer.

Calibrate the variable speed pump to the selected rate so that at the start of the constant discharge test early fluctuations in flow rates will be minimized.

Allow the aquifer to fully recover for a period equal to or greater than the duration of the step-test prior to initiating the constant-discharge test.

3.3 SLUG TESTS

Slug tests involve the use of a single well, and evaluating its response to an instantaneous raising and/or lowering of the water level within the casing. If the well is poorly designed or poorly developed, the test may end up evaluating the performance of the well screen and/or filter pack rather than the aquifer.

Slug tests are usually of short duration, usually less than 5 minutes. The first 30 seconds are the most important in respect to data collected. Piezometers and digital data loggers are, therefore, a must.

3.4 DATA REDUCTION

If the data were recorded by the datalogger as feet of water above the pressure transducer, reduce these data to potentiometric head (in feet), relative to the initial water level as measured from the top of the casing. Record this with the respective changes in time. For each piezometer or well, tabulate the pre- and post-test water levels, dates, clock times, and times since pumping started or stopped.

Tabulate measurements of the rate of discharge at the control well, date, clock time, time since pumping started, and method of measurement.

Prepare a written description of each well, describing the measuring point, giving its elevation and the method of obtaining the elevation, and the distance of the measuring point above the mean land surface.

Once the data are collected and reduced, a variety of methods may be used to calculate aquifer parameters from pumping test data. Refer to Section 5 for analytical methods applied to test data.

Data can also be reduced electronically when downloaded from the transducers into software such as AQTESOLV®; this is software designed to calculate hydraulic conductivity, storativity and other aquifer properties from data sets collected during slug and aquifer (pumping) tests.

Text files, which are generated by commonly used pressure transducers, can be imported into the software and data can also be manually entered or pasted from a spreadsheet. After importing, the raw data can be manipulated using mathematical functions. For example, hydraulic head data can be converted to drawdown data. The program will also produce visual and automatic curve matching methods for confined, unconfined and leaky aquifers. Visual curve matching is analogous to traditional methods of aquifer test analysis with graph paper and type curves. The software is also capable of producing error logs which enable the user to quickly identify any deficiencies or inconsistencies detected in the data set.

4. FIELD DATA RECORDS

4.1 LOGBOOK

Only one site or installation per logbook, and only one slug test per data table (see below). The first page must include the well number, location, date of test, persons conducting the test, and reference plane for drawdown measurements. Next page(s) must be in table format with the columns designating time/date, water volume withdrawn/added or displaced by inert cylinder, water levels, etc.

Test data must be entered in a table as data are acquired. Data must include sufficient information to indicate that the water level was stable before the test, during equilibrium, and after the test(s).

5. INTERPRETATION OF DATA

5.1 CONFINED AQUIFER METHODS

5.1.1 Theis Method

The Theis test method involves pumping a well (pumped well) at a constant rate (Q) and measuring drawdown (s) in an adjacent observation well. Theis assumed that groundwater flow in an aquifer is analogous to heat flow in a solid and derived the following equation:

$$s = \frac{Q}{4\pi T} \int_{r^2 \frac{s}{4Tt}}^{\infty} \left(\frac{e^{-u}}{u} \right) du$$

Equation 1

where

- s = Drawdown.
- r = Radial distance to observation well.
- Q = Pumping (discharge) rate.
- T = Transmissivity (K × aquifer thickness).
- K = Conductivity.
- S = Storativity.
- t = Time (since pumping began).

and

$$u = \frac{r^2 S}{4Tt}$$

Equation 2

If the integral is expressed as the well function W(u), then the equation can be written as:

$$s = \frac{Q}{4\pi T} W(u)$$

Equation 3

which can be also written as:

$$T = \frac{Q}{4\pi s} W(u)$$

Equation 4

or

$$S = \frac{4Tt}{r^2} u$$

Equation 5

5.1.1.1 Assumptions

To permit an analytical solution for non-steady, radial flow into the well, the Theis method makes the following assumptions. Most of these assumptions are incorporated in the other analysis methods detailed herein. Only exceptions or additions to these assumptions will be noted in each method.

- The aquifer has seemingly infinite areal extent compared to the well, whose diameter is assumed infinitesimally small.
- The aquifer is homogeneous, isotropic, of uniform thickness, and horizontal.
- The head is uniform and constant prior to the test.
- Darcy's Law is valid.
- The well is pumped at a constant rate.
- Water is discharged from storage instantaneously.
- The well screen fully penetrates the aquifer.
- Flow within the aquifer is radial to the well and strictly horizontal.
- Drawdown data are taken from an adjacent observation well.

One additional assumption is made in this SOP, which was not made by Theis: The pumping well has been previously sampled and analysis of the groundwater at that site is not grossly contaminated (e.g., no non-aqueous phase liquids).

5.1.1.2 Procedure (see also ASTM D4106-91 and D4050-91)

Field Operations – Constant Discharge Test (Refer to Section 3.2.1)

Data Plots

1. Prepare a type curve of $W(u)$ over $1/u$ on log-log paper. Figure SOP033-1 is an example of a type curve. Tables of data used to generate this curve may be found in ASTM D4106-91, ASTM D5270-92, or in most hydrology texts such as Fetter or Dominico⁴. It is recommended that this plot be copied onto tracing paper, drafting film, or an overhead viewer film copy be made to facilitate later steps. NOTE: $W(u)$ over u can be plotted if preferred, but will require additional computational steps if used.
2. Plot drawdown over time for each observation well on log-log paper which has the same scale as the type curve (above). Note that for a single observation well, drawdown can be plotted as a function of time (t). However, for multiple observation wells, drawdown can be plotted as a function of t/r^2 , where r = radial distance from the pumping well to the observation well in which the measurements were made. This is done to normalize the data and allow comparison between wells.

4. See Section 6 for complete citations of these references.

3. Superimpose the type curve and the plot of observation well data. **Keeping both the X and Y axis of each plot parallel**, position the two curves to obtain the best match when overlain. NOTE: If only paper copies of both plots are available, a light table or brightly lit window will be required for this step.
4. Select a match point on the overlapping portion of the two graph papers such that the values for that point simplify the calculations (e.g., even log cycles of $[W(u), 1/u]$ — $[1,1]$; $[1,10]$ etc.).
5. Read coordinates for $W(u)$, $1/u$, s , and t .
6. Substitute the match point values for the appropriate variable in Equations 3, 4, and 5.
7. Repeat for each observation well.

5.1.2 Modified Theis (Cooper & Jacob; Jacob) Method (see also ASTM D4105-91)

5.1.2.1 General

From Equation 1, we have:

$$\int_0^{\infty} \left(\frac{e^{-u}}{u} \right) du = W(u) = -0.577216 - \log_e u + u - \frac{u^2}{2!2} + \frac{u^3}{3!3} - \frac{u^4}{4!4} + \dots$$

Equation 6.

Jacob noted that as values of u become small, the value of the series to the right of $\log_e u$ becomes insignificant. That is the series becomes equal to or less than 0.01. The value of u decreases as the value of t (time) increases, and as the value of r (radial distance to observation well) decreases. Therefore, for long pumping times and/or observation wells reasonably close to the pumping well, the Theis equation can be stated as:

$$s = \frac{Q}{4\pi T} \left[-0.577216 - \ln \left(r^2 \frac{S}{4Tt} \right) \right]$$

Equation 7.

Lohman was then able to show the following relationships:

$$T = \frac{2.3Q}{4\pi \Delta s / \Delta \log_{10} t}$$

Equation 8

and

$$T = \frac{2.3Q}{4\pi \Delta s / \Delta \log_{10} r}$$

Equation 9

where

- $\Delta s / \Delta \log_{10} t$ = The drawdown (measured or projected) over one log cycle of time.
 $\Delta s / \Delta \log_{10} r$ = The drawdown (measured or projected) over one log cycle of radial distance from the control well.

5.1.2.2 Procedure

Field Operations (see Field Operations under Section 3.2.1.1)

Data Plots

1. Plot drawdown over time (log scale) on semilog paper.
2. Draw a best fit straight line through the later portion of the data and project it back to $s = 0$.
3. Read t_0 as the time corresponding to the $s = 0$ point.
4. Solve for T using:

$$T = \frac{2.3Q}{4\pi\Delta s} \quad \text{Equation 10}$$

5. Solve for S using:

$$S = \frac{2.25Tt_0}{r^2} \quad \text{Equation 11}$$

where

t_0 = the intercept of the line when extended to the zero drawdown axis.

6. Solve for K ($K = T/\text{aquifer thickness}$). Aquifer thickness = screened interval (see assumptions in Section 5.1.1.1).
7. Repeat for each monitoring well.

5.1.3 Thiem (Steady State Flow) Method

5.1.3.1 Assumptions

All of the Theis assumptions hold except that equilibrium has been reached between discharge and drawdown. Note that this condition is theoretically impossible in a confined aquifer where all discharge is derived from storage.

5.1.3.2 Equations

When these assumptions are met, the following equation expresses groundwater flow in the confined aquifer:

$$Q = \frac{2\pi T(s_1 - s_2)}{\ln\left(\frac{r_2}{r_1}\right)} \quad \text{Equation 12}$$

where

Q = Well discharge.

T = Aquifer transmissivity.

r1 and r2 are respective distances of OW-1 and OW-2 from the pumping well.

s1 and s2 are respective steady-state drawdowns in the observation wells.

Note that the Thiem equation is designed to solve for transmissivity only, and cannot be used to solve for storativity.

5.1.3.3 Procedure

Field Operations

1. Follow Steps 1 through 9 in Section 3.2.1.
2. Continue pumping until steady-state conditions are reached. This equilibrium is defined as the time when variations of drawdown with respect to time are negligible. Note that this may require considerably more time than with either the Theis or Modified Theis methods described above.

Data Plots Method 1

1. Substitute the steady-state drawdown of the two observation wells into Equation 12 along with the values of r and Q. Solve for T.
2. Repeat with all possible combinations of observation wells to obtain the mean transmissivity of the aquifer.

Data Plots Method 2

1. Plot the observed steady-state drawdown of each observation well over distance (log scale) to the pumping well.
2. Construct a best-fit straight line through the plotted points.
3. Determine the maximum drawdown per log cycle.
4. Substitute this value of (s1 - s2) in Equation 12 along with Q and solve. Note that the term $\ln(r2-r1)$ is taken to $\ln(10)$ equal to 2.30.

5.2 BOUNDED, NON-LEAKY, CONFINED AQUIFER

The test methods described in this section are essentially duplicates of the Theis and Modified Theis methods which are detailed above. The principal differences are that, by definition, a

bounded aquifer is limited in its areal extent by a fully-penetrating linear boundary, which is either a constant head (e.g., stream or lake) or a no-flow boundary (e.g., impermeable, or significantly less permeable geologic formation). These conditions are illustrated on Figure 2.

As stated, the equations used to evaluate data derived from bounded wells are modifications to the basic Theis equations. Drawdown(s) at any point in the aquifer is defined as the sum of the drawdown due to the real (s_r) and image (s_i) wells such that:

$$s_0 = s_r \pm s_i \quad \text{Equation 13}$$

so that Equation 1 can be rewritten as:

$$s = \frac{Q}{4\pi T} [W(u_r) \pm W(u_i)] = \frac{Q}{4\pi T} \sum W(u) \quad \text{Equation 14}$$

where

$$u_r = \frac{r_r^2 S}{4Tt} \quad \text{Equation 15}$$

and

$$u_i = \frac{r_i^2 S}{4Tt} \quad \text{Equation 16}$$

so that:

$$u_i = \left(\frac{r_i}{r_r}\right)^2 u_r \quad \text{Equation 17}$$

or

$$u_i = K_1^2 u_r \quad \text{Equation 18}$$

where

$$K_1 = \frac{r_i}{r_r} \quad \text{Equation 19.}$$

NOTE: K_1 is a constant of proportionality and should not be confused with the hydraulic conductivity.

5.2.1 Assumptions

All assumptions listed under the Theis method apply with these exceptions:

- The non-leaky aquifer is of infinite areal extent except where limited by linear boundaries.
- The boundaries are vertical planes of infinite length, which fully penetrate the aquifer.
- The hydraulic boundaries are perfect. Impermeable boundaries yield no water to the aquifer; recharge boundaries are in perfect hydraulic connection with the aquifer.

5.2.2 Procedure (see also ASTM D5270-92)

Field Operations (see Section 3.2.1.1)

Data Plots

1. Generate a family of type curves for the solution of the modified Theis formula (K1). This family of curves should include curves for both discharging and recharging image wells. Plot the coordinates of $\sum W(u)$ on the vertical axis and $1/u$ (Figure 3). It is recommended that this plot be copied onto tracing paper, drafting film, or an overhead viewer film copy be made to facilitate later steps.
2. Plot drawdown (s) over t/r^2 for each observation well on log-log paper which has the same scale as the type curve (above). NOTE: **t=time, r=radial distance from pumping well.**
3. Superimpose the type curves and the plot of observation well data. **Keeping both the X and Y axis of each plot parallel**, position the two curves to obtain the best match when overlain. NOTE: If only paper copies of both plots are available, a light table or brightly lit window will be required for this step.
4. Select a match point on the overlapping portion of the two graph papers such that the values for that point simplify the calculations (e.g., even log cycles of $[\sum W(u), 1/u]$ — $[1,1]; [1,10]$ etc.).
5. Read coordinates for $\sum W(u)$, $1/u$, s, and t/r^2 .
6. Substitute the match point values for the appropriate variable in the equations below:

$$\text{Transmissivity} = T = \frac{Q}{4\pi s} \sum W(u)$$

Equation 20

$$\text{Storativity} = S = 4T \left(\frac{t}{r^2} \right) u$$

Equation 21

7. For each OW, determine the distance from the image well (r_i) using the following:

$$r_i = K_f r$$

Equation 22

8. Repeat for each observation well.

5.2.3 Modified Theis Non-Equilibrium Method

As in the case of a non-bounded aquifer, the hydraulic parameters can also be determined using a Modified Theis equation and a straight line (semi-log) plot of s and $\log_{10} t$.

5.2.3.1 Procedure

1. Refer to Section 5.1.2 (above) and ASTM D4105-91 for details on plotting the data and the equations to be used in calculating transmissivity and storativity using this method. Note that the data will define two rather than one straight line portions. This is due to the image well effect of the boundary conditions.
2. Select a convenient value of s within the initial straight-line part of the plot. Drawdown represented by this portion of the curve has not been affected by the boundary. Therefore, $s = s_r$ and the corresponding value of t_r corresponds to s_r .
3. Graphically extend the initial straight-line part of the curve to the right. The departure of the measured drawdown from the extended line represents the drawdown due to the presence of the boundary. This effect is also referred to as the image well drawdown, s_i .
4. Select a point on the second straight-line such that $s_i = s_r$. Note the value of time t_i which corresponds to s_i .
5. Since t_r and t_i are selected such that $s_i = s_r$, then $u_r = u_i$ and (Equation 23)

$$\frac{r_r^2 S}{4Tt_r} = \frac{r_i^2 S}{4Tt_i}$$

so that:

$$K_t = \frac{r_i}{r_r} = \sqrt{\frac{t_i}{t_r}} \quad \text{(Equation 24)}$$

6. Determine the distance to the image well using Equation 22.
7. Repeat this calculation for each observation well.

Determine the location of the boundary as follows:

- Accurately plot the locations of the control and observation wells on a map.
- With a compass, using each observation well as the center point, draft a circle which has a radius equal to the distance from that well to the boundary.
- The image well is located at the intersection of these circles. If the circles do not intersect exactly, the probable well location is at the centroid of the intersections, or the polygonal area bounded by the circles in the case of no overlap.
- Draw a straight line from the pumping well to the image well. The boundary is defined as the perpendicular bisector to this line at the image well.

5.2.4 Limitations

The following caveats apply to either of the above two methods:

- In cases where this test method is employed to locate an unknown boundary, a minimum of three observation wells is required to accurately locate the image well which is the boundary. Two observation wells will yield two possible locations for the image well. One observation well will indicate the presence of a boundary, and the distance (radius) from the observation well, but the image well will be located somewhere on that surface.
- The effects of a constant head (recharging) boundary are indistinguishable from those of a leaky aquifer. It is, therefore, imperative that care be taken in developing the conceptual model of the geohydrologic system being studied prior to testing.

5.3 SEMI-CONFINED (LEAKY) AQUIFER

In some instances, the confining beds either above or below the aquifer will not be completely impermeable. In these cases, the aquifer is said to be “leaky.” This condition can be readily determined from the Theis s over t plot on log-log paper. In the initial phase of pumping, the plot will look like the Theis “type” curve. As pumping continues and the aquifer is depressurized (piezometric head decreases), a gradient within the overlying and/or underlying aquitard(s) is induced. Instead of the expected type curve, the plot will be somewhat flattened, and values for s may actually decrease over time if the vertical component of groundwater flow through the aquitard(s) is sufficiently high. The log-log plot will yield a considerably flattened curve. This is one of the reasons it is recommended that these log-log plots be done in the field, so that such conditions can be detected early, and steps be taken to minimize any adverse environmental impact of aquifer cross contamination.

5.3.1 Neuman and Witherspoon Method

The Neuman and Witherspoon approach to solving the problem of evaluating a leaky aquifer is two-fold. First, they assumed that if the distance between observation well and pumping well is minimized, the area of aquitard subjected to stress and possible leakage is minimized, and the Theis method could be employed. Next, they assumed that if only early time drawdown data were used, the effects of leakage could be further reduced. This is accomplished by closely monitoring the response curve(s) for transducers both in the aquifer and in the aquitard(s) themselves. When the s over t curve begins to flatten, indicating leakage, this is defined as the end of valid aquifer data. Data acquired beyond that point contains components of horizontal (aquifer) flow, and vertical (aquitard) flow. In order to accurately calculate the aquitard parameters, an undisturbed sample of the aquitard must be taken (ASTM D1587-83). The laboratory tests will provide values for storage of the aquitard(s). Conductivity within the aquitard(s) is provided from the s over t plots for transducers located within the aquitard.

5.3.1.1 Assumptions

The same assumptions as in the Theis method hold with the following differences:

- The aquifer is leaky.
- The aquifer and aquitard both have a seemingly infinite areal extent.
- Flow in the aquitard is vertical.
- Drawdown is negligible in both aquifer and aquitard.
- The aquitard has storage.
- The overlying and/or underlying aquifer(s) is capable of releasing water to the pumped aquifer through a decline in head.

5.3.1.2 Procedure

Field Operations

1. See field operations in Section 3.2.1.1.
2. In addition, set piezometers within the aquitard at 0.25 and 0.50 aquitard thickness. These should be set at essentially the same location as the observation well, either in the observation well or in a separate borehole adjacent to the observation well, and the same radial distance from the pumping well.

Data Plots

1. Prepare log-log plots of s over t for the observation well and transducers placed in the aquitard.
2. Use the valid early-time data and the Theis method to calculate the pumped aquifer parameters.
3. Calculate several s'/s ratios for the early time period used in b above.
4. Calculate the parameter t_D — a “dimensionless” time parameter — using the following equation:

$$t_D = \frac{Kt}{Ss^2}$$

Equation 25

where

- t = Time.
- r = Radial distance to observation well (and transducers).
- K = Pumped aquifer hydraulic conductivity.
- S = Pumped aquifer storativity.

5. Using the value tD calculated in d (above), and s'/s, determine a value for t'D using Figure 4.

5.3.2 DeGlee Method and Hantush Approximation

DeGlee developed the following equation for steady-state drawdown within an aquifer with leakage from an aquitard proportional to the hydraulic gradient across the aquitard:

$$s = \frac{Q}{2\pi T} (K_0) \frac{r}{L} \quad \text{Equation 26}$$

where

- T = Transmissivity.
- s = Steady-state drawdown in observation well at distance r from pumping well.
- Q = Discharge rate of pumping well.
- L = Tc = leakage factor.
- c = D'/K = hydraulic resistance of the aquitard.
- D' = Saturated thickness of the aquitard.
- K' = Hydraulic conductivity of the aquitard for vertical flow.
- K0(x) = Modified bessel function of the second kind and of zero order (Hankel function).

Hantush observed that if r/L is small (0.05), Equation 14 can be estimated by:

$$s = 2.30 \frac{Q}{2\pi T} (\log 1.12 \frac{L}{r}) \quad \text{Equation 27}$$

5.3.2.1 Assumptions

See Section 5.3.1.1.

- Flow to the pumping well is in steady state.
- L is greater than 3D, where D is the saturated thickness of the aquifer.

5.3.2.2 Procedure

Field Operations

Field methods are identical to the Thiem method in Section 5.13.

Data Plots

Plot s over r (log scale) on semi-log paper where r/L is small, the points fall in a straight line plot. Where r/L is large, the curve approaches the zero-drawdown axis asymptotically.

5.3.3 Other Methods for Calculating Leaky Aquifer Parameters

The Neuman and Witherspoon Unsteady-state flow method, the Hantush Curve-Fitting Method, the Hantush Inflection Point Method, and the Walton Method. As before, these are mentioned for the sake of completeness, but not detailed herein.

5.4 UNCONFINED AQUIFERS

Flow to a pumping well in an unconfined (phreatic or water table) aquifer occurs in three phases. In the first phase, pumping has just begun, and the aquifer acts like a confined aquifer. Water is derived from storage (expansion of the water, compression of the aquifer). The time over drawdown plot for this phase closely mimics the Theis type curve. During the second phase, delayed yield occurs. This phenomenon results as water remaining in the pores is drained by gravity (specific yield), replenishing the portion of the aquifer supplying water to the well during the first phase, and results in a reduction in rate of drawdown over the first phase, and a flattening of the time-drawdown plot. The third phase brings equilibration in the rate of drawdown and the time-drawdown plot again looks like the Theis curve.

The duration of the first two phases is a function of the ratio of storage (S) to specific yield (S_y). If the ratio is in the range of 10^{-1} to 10^{-2} , S is relatively large and the first phase drawdown should be significant. This condition is typical of saturated fine-grained sediments such as silts, clays, and fine-grained sands. If the ratio S/S_y is in the range of 10^{-4} to 10^{-6} , S_y is relatively large, the second phase phenomenon is expected to be dominant, and coarser-grained sediments (sands and gravels) are indicated.

In addition to S/S_y , the distance between pumping well and observation well also affects the time-drawdown plot. As the distance to the observation well increases, the effects of S decrease.

5.4.1 Neuman Method

Flow to a pumping well in an unconfined (phreatic, or water table) aquifer occurs in three stages. During the first stage, the phreatic aquifer behaves like a confined aquifer, instantaneously releasing water from storage (expansion of the water, compression of the aquifer). This is

illustrated in Figure 5, where the early portion of the family of drawdown curves closely matches the Theis curve ($1/uA$). The second phase is termed a period of “delayed yield” or “delayed response,” in which the rate of drawdown is lower than that predicted by the Theis curve. During this phase, specific yield, or gravity drainage of water remaining in the pore spaces in the vicinity of the pumping well replenishes the water being removed. During the third phase, the rates of yield and drawdown equilibrate, and the time-drawdown plots again converge on the Theis solution ($1/uB$).

5.4.1.1 Assumptions

- The same assumptions as listed in Section 5.1.1.1.
- At least one observation well located at $r/b \leq 1$, where r = distance between pumping well and observation well, and b = aquifer thickness.

Drawdown in the observation well $s \leq 0.25 b$.

5.4.1.2 Procedure

Field Operations

See Section 3.2.1.

Data Plots

1. Prepare A and B curves (Figure 5); tables of these values can be found in many hydrology texts such as Fetter
2. Plot s over t on log-log paper at the same scale as the Type A and B curves
3. Superimpose the late-time drawdown data over the B curves. Note the value for the curve which best matches the field data.
4. Select a match point which has a value of 1 for as many of the variables as possible.
5. At the selected match point, read values for s , t , $W(uB, \beta)$ and $1/uB$
6. Repeat steps a-e, superimposing the early time data over the A curve which has the same β value as the B curve.
7. Read values for s , t , $W(uA, \beta)$ and $1/uA$
8. Substitute these values in the following equations:

$$T_B = \frac{Q}{4\pi s} (W(u_B, \beta))$$

Equation 28. Transmissivity B curve.

$$T_A = \frac{\psi}{4\pi s} (W(u_A' \beta))$$

Equation 29. Transmissivity A curve.

$$S_y = \frac{4T_B t u_B}{r^2}$$

Equation 30. Specific Yield.

NOTE: Transmissivities should be within ± 10 percent of each other. If they are, their average should be used in the remaining equations, otherwise use the T value from the B curve.

5.5 SLUG TESTS

5.5.1 Preliminary to Operation (All Slug Tests)

Prior to conducting any tests, water level meters, transducers, dataloggers, and other materials should be examined for cleanliness and checked for defects.

Batteries should be checked in the calculator(s), water level meter(s), and datalogger(s).

Decontaminate all intrusive equipment prior to and after use at each location.

Lay plastic sheeting on the ground around the well casing.

Record the well number and other project and site information in the field logbook.

Check the well headspace for the presence of volatile organic compounds using applicable instruments. Record the results in the field logbook.

Measure and record the initial water level in the well and total depth of the well.

NOTE: If the static water level and water levels caused during testing are above the top of the screened, or the well consists of an open hole with no casing, then both rising-head and falling-head tests should be conducted.

If the static water level is at or below the top of the screened or open-hole interval, a rising-head test only should be conducted (i.e., falling-head slug tests are invalid for this situation).

5.5.2 Option 1 – Inert Object Insertion

This procedure describes the use of a solid slug to change the water level in a well.

Select an appropriate transducer for the range of water level change anticipated in the slug test.

Submerge the transducer in the well to a sufficient depth to provide effective performance. The range of the transducer must be considered in the determination of the submersion depth. Well bottom sediment plugging of the transducer must be avoided as well as transducer interference by the inert object.

Monitor water level until it returns to original level as measured in Section 5.5.2 before initiating the test.

Tie off the line to a decontaminated, inert cylinder (slug) prior to lowering it into the well. All intrusive equipment must be decontaminated.

“Instantaneously,” but smoothly, lower the cylinder into the well, displacing the water and thereby raising the water level.

Measure and record water levels in the well initially. Record the water level response during cylinder insertion and every 5-10 seconds with the cylinder in place. Record the falling water level and time of each measurement in the field logbook and/or Field Permeability Test Data Sheet.

NOTE: If transducer and datalogger are employed, care must be taken to create backup copies and/or hardcopies of these data as soon as practicable.

Record data until water level has stabilized, or approximately 90 percent of the change in the water level has dissipated. The time for this to occur may range from less than 1 minute to more than a day. Usually, it is not necessary to continue measurements for more than a few hours because longer periods indicate extremely low hydraulic conductivity. Choose the time interval between measurements according to how rapidly the water level approaches the static level. From 10 to 30 measurements should be obtained at approximately equal time intervals during the recovery.

“Instantaneously,” but smoothly, remove the cylinder from the well.

Conduct a rising head slug test by measuring the response of the water level to the removal of the cylinder. Record water levels and time until the water level equilibrates to 90 percent of the initial level, and record data as in Section 5.5.2.

Calculate the aquifer hydraulic conductivity using appropriate equations.

Decontaminate the slug and the tape or meter.

5.5.3 Option 2 – Adding or Removing Water

This procedure describes the use of a pump to change water level in a well and a datalogger and pressure transducer to measure the water level. The technique is intended for use in wells installed in highly permeable materials where the use of a slug may not induce a measurable

change in the water level. However, this technique can also be used in wells installed in low permeability materials. The methods described for the transducer/datalogger are also appropriate when using a solid slug or bailer for inducing a change in the water level in a well.

Select an appropriate transducer for the range of water level change anticipated in the slug test.

Submerge the transducer in the well to a sufficient depth to provide effective performance—usually this is to a depth at which its pressure rating is not exceeded but no less than 5 ft of water is above the transducer. The range of the transducer must be considered in selection of the submersion depth.

Check the transducer calibration at two different depths in the well. The transducer should be at least 1 ft above the bottom of the well to prevent bottom sediment from fouling the transducer and preventing accurate readings.

Turn on the datalogger to view the water level value (either in depth of submergence or depth to water).

IF REMOVING WATER: Insert the pump piping with check valve (if using a centrifugal pump) or submersible pump with check valve into the well at least 4 ft below the water table but above the transducer. Attach pump discharge to treatment system, portable tanks, or drums to containerize the effluent if it is known or suspected to be contaminated.

— OR —

IF ADDING WATER: Insert piping from water source to a depth of about 1 ft below the surface of the water table (this will prevent undue aeration of the water column and possible anomalous readings).

Monitor water level until it returns to original level as measured in Section 3.1.2 before initiating the water addition/extraction test.

View water level value on datalogger. Values (either depth of submergence or depth to water) should be stable and approximately the same range as in Step C; if not, wait until the water level equilibrates to the initial value.

Begin logging and record the time.

Turn pump on until 4-5 ft of drawdown occurs or the well (at the depth of the poly pipe or pump) goes dry.

— OR —

Turn on water at supply tank until the water level in the well rises a minimum of 5 ft.

Shut off pump or water supply at the tank. Remove piping or pump to a position above the initial water level (water removal) or remove from the well (water addition or removal).

Record water levels and water volumes removed/added during the entire test.

Record water levels until approximately 90 percent of the change in the water level has dissipated. The time for this to occur may range from less than 1 minute to more than a day. Usually, it is not necessary to continue measurements for more than a few hours, because longer periods indicate extremely low hydraulic conductivity.

Periodically collect water levels manually using an electronic water level meter of tape to verify the datalogger values.

End logging and record the time. Remove the poly pipe and/or pump and pressure transducer and transfer data in datalogger to a computer disk. Make a backup copy of the file and record the file information in the field logbook.

Decontaminate intrusive equipment.

Calculate the aquifer hydraulic conductivity using appropriate equations.

5.5.4 Data Plots

Record the water level in the well immediately after the inert object emplacement/withdrawal (Option 1) or at the equilibrium of the water table (Option 2). This is the initial water level reading.

Following the initial water level reading, the water level in the well is continuously recorded along with the time of the level measurement.

The ratio of the initial water level to the change in head is plotted with respect to time.

The ratio is plotted on the arithmetic scale and time is plotted along the logarithmic scale.

The relationships of the initial water level to changes in the water level are a function of parameters shown on Figure 6 and the formation transmissivity. The values of the function relationship are plotted for a series of transmissivities and are depicted in Figure 5.

The resulting field data plot (curve) is compared to a series of type curves (Figure 5). The field-data curve is placed over the type curves with the arithmetic axis coincident. The field data curve is matched to the type curve that has the same curvature.

The formation transmissivity is determined.

The value of storativity is calculated.

6. REPORTS

After performing hydrologic tests, the contractor will generate a report which must contain a minimum of the following elements:

- A field data report including a site description, plots of water level and discharge with time, and a precursory analysis of data.
- The introduction should include the purpose of the test, dates and times water-level measurements were begun, dates and times discharge or injection was begun and ended, and the average rate of discharge or injection.
- Well logs (including construction diagrams) of all control wells, observation wells, and piezometers.
- Site map showing all well locations, distances between wells, and locations of all geologic boundaries or surface waterbodies which might affect the test.
- The locations of wells and boundaries which may affect the test generally need to be accurate within a radial distance of ± 0.5 percent. For large-scale studies, it may be sufficient to locate wells from maps or aerial surveys. Small-scale studies require that well locations be surveyed. Additionally, other features such as faults, streams, and canals should be located. Well deviation surveys, which determine true horizontal distance between well screens, may be necessary if test wells are deep relative to their spacing.

7. MAINTENANCE

The transducers must be kept clean, operable, and thoroughly tested before emplacement in the well. A plugged or malfunctioning piezometer will give erroneous responses or fail to give any response.

8. PRECAUTIONS

In the case of slug tests, care should be exercised to maximize the efficiency of the well. If there is a great disparity between the conductivity of the aquifer and that of the well screen/filter pack, one may find that the slug test has accurately measured the conductivity of the well screen/filter pack rather than the aquifer.

Transducers should be double checked to ensure that they are calibrated in the correct water level range. Water level and well depth should be checked with an electronic water level meter or steel tape before and after placing the transducers.

Be sure that the wells used are well developed.

If the water removed is contaminated and cannot be discharged at the surface, a tank of sufficient size to hold the effluent of the pumping test must be available.

9. REFERENCES

American Society for Testing and Materials (ASTM). D4043-91 Guide for Selection of Aquifer-Test Method in Determining Hydraulic Properties by Well Techniques.

ASTM. D4044-91 Test Method for (Field Procedure) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers.

ASTM. D4050-91 Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems.

ASTM. D4104-91 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Over-Damped Well Response to Instantaneous Change in Head (Slug Test).

ASTM. D4105-91 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method.

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ASTM. D4630-86 (1991) Test Method for Determining Transmissivity and Storativity of Low-Permeability Rocks by *In Situ* Measurements using the Constant Head Injection Test.

ASTM. D4631-86 (1991) Test Method for Determining Transmissivity and Storativity of Low-Permeability Rocks by *In Situ* Measurements using the Pressure Pulse Technique.

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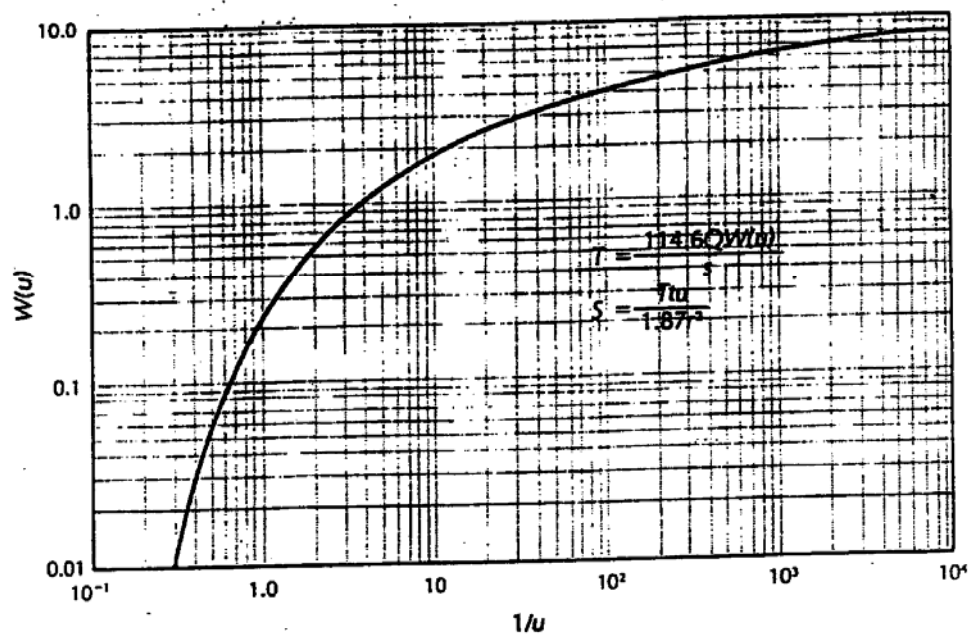


Figure SOP033-1. Theis type curve (after Fetter).

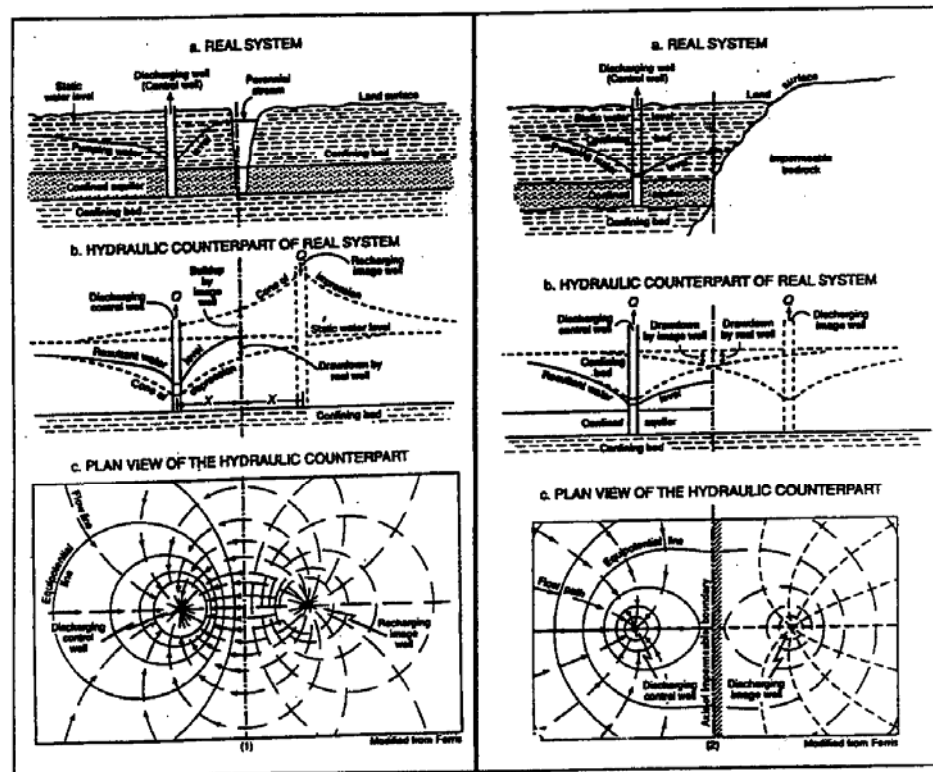


Figure SOP033-2. Illustration of boundary conditions
(after ASTM D-5270-92).

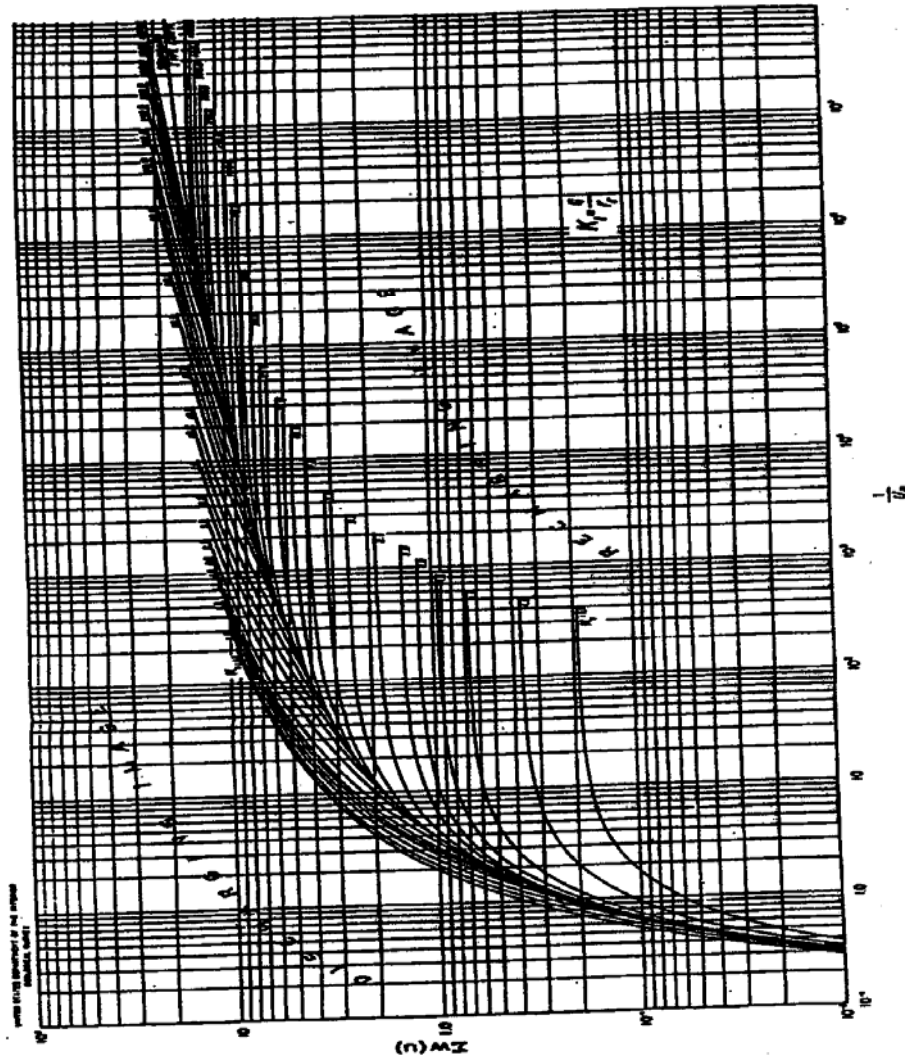


Figure SOP033-3. Family of type curves for the solution of the Modified Theis formula (after ASTM D-5270-92).

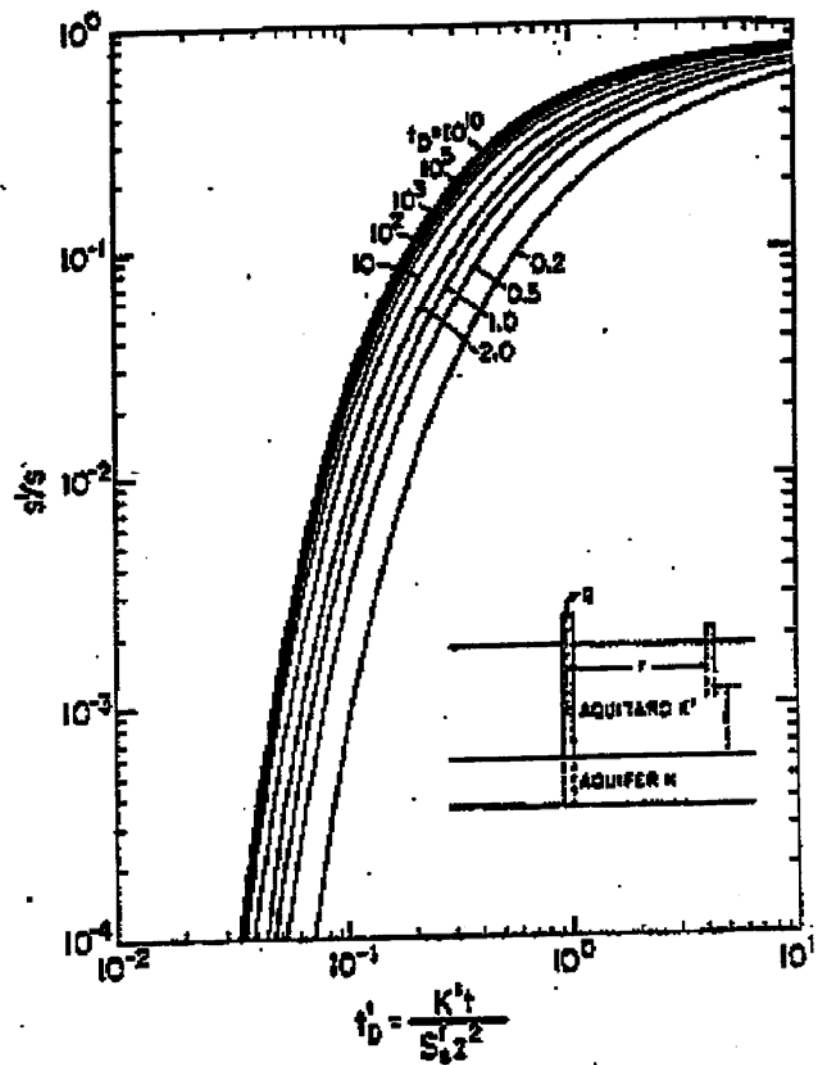


Figure SOP033-4. Variation of s'/s with t'_d for a Semi-Infinite Aquitard (after Reynolds).

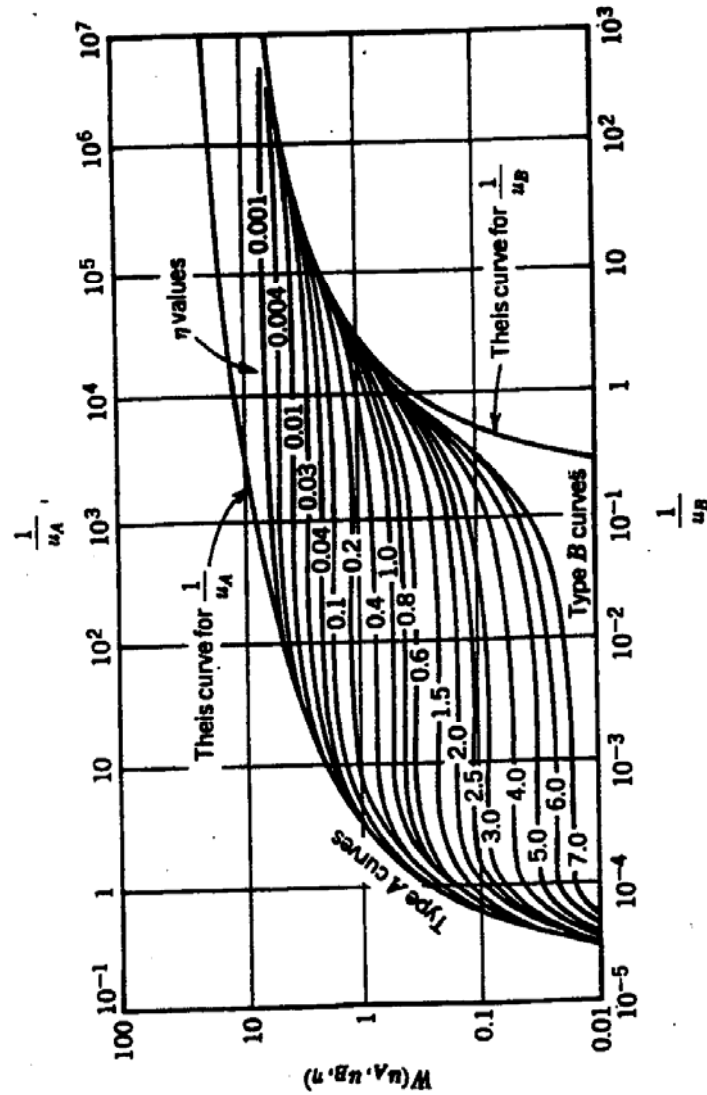


Figure SOP033-5. A and B type curves (after Dominico).

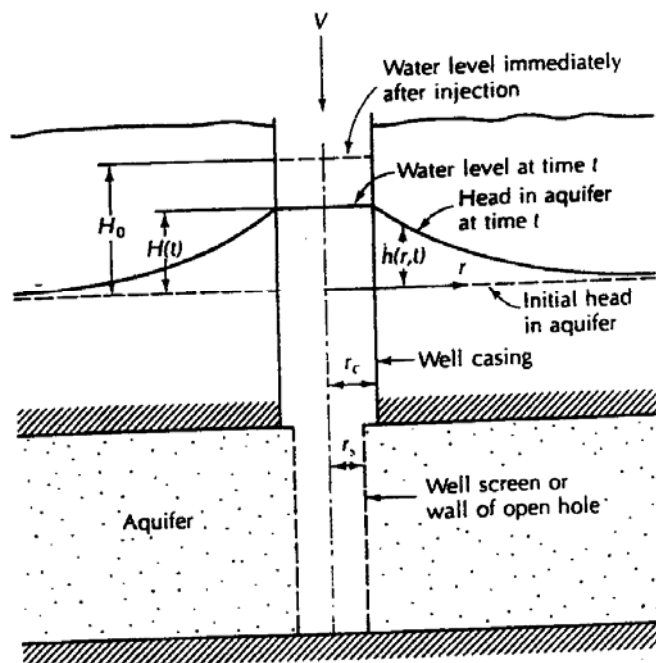


Figure SOP033-6. Well parameters – slug tests (after Fetter).

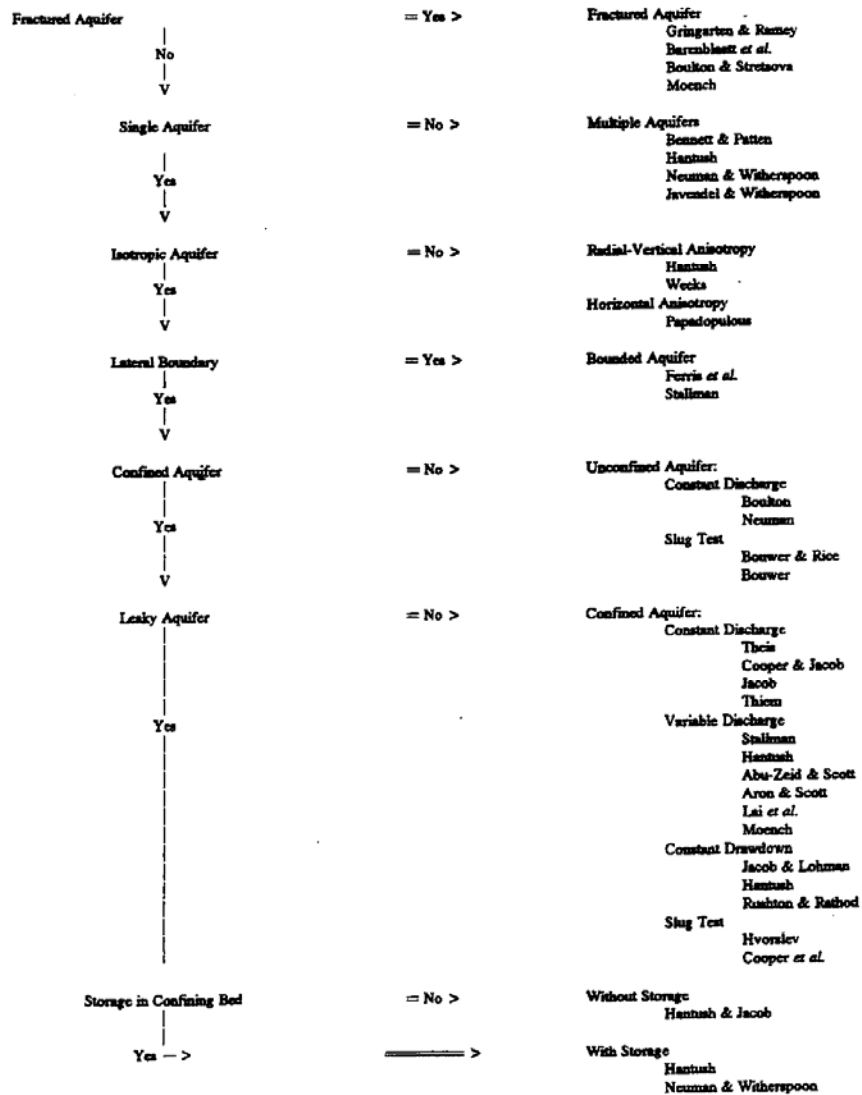


Table SOP033-1. Decision tree for selection of aquifer test method (after ASTM D-4043-91).



Standard Operating Procedure No. 036 for Turbidity Measurements (DRT 100)

Prepared by

EA Engineering, Science, and Technology, Inc.
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Revision 0
August 2007

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the turbidity of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. Turbidity is an indication of the optical properties that cause light to be scattered or absorbed through an aqueous sample. Turbidity is largely a function of the refractive index and the size and shape of the particles suspended or dissolved in the solution. Turbidity meters do not produce an “absolute” measurement, but one that is “relative” to the optical nature of the solids in solution.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

Turbidity meter (DRT 100 or equivalent)
Lint free laboratory wipes (Kimwipes or equivalent)
Formazin standards (from manufacturer)
Sample bottle
Cuvettes

3. PROCEDURE

Calibration of the turbidity meter will be checked on a daily basis as follows:

- Set the range switch to 1000 range before turning the turbidity meter on and whenever the light shield is not in place over the sample well.
- Allow the turbidity meter 15-60 minutes to warmup.
- Clean the reference standard with kimwipes.
- Place the formazin suspension or reference standard in the turbidity meter sample well.
- Place the light shield over the reference standard.
- Rotate the front panel range switch counterclockwise to the appropriate nephelometric turbidity unit range.

- Adjust the reference adjust knob counterclockwise to read the same value as the reference standard value. This value is stamped on top of the reference standard.
- The turbidity meter is now standardized on all ranges to the factory formazin calibration and unknown samples may be read directly in nephelometric turbidity unit, feeder terminal unit, or Jackson turbidity unit.
- Rotate the range switch clockwise to the 1000 range before removing the reference standard.
- Record reading in field logbook (Refer to SOP Nos. 003 and 016).
- Do not leave the reference standard in the sample well for long periods.

Turbidity will be measured as follows:

- Pour aqueous sample into a new cuvette assuring no air bubbles.
- Place the cuvette into the sample well.
- Place the light shield over the sample.
- Rotate the range switch counterclockwise to the range which provides best readability and sensitivity for the sample being measured.
- Allow the turbidity meter to stabilize before recording the nephelometric turbidity unit value.
- Turn the range switch clockwise to the 1000 range and then remove the sample.
- Do not leave the filled cuvette in the sample well for long periods.
- Repeat above steps for additional samples.

Cuvette cleaning procedure is as follows:

- Cuvette must be clean and free of rubs or scratches.
- Wash the cuvette in a detergent solution.
- Rinse thoroughly 8-10 times, preferably with distilled water to remove all streaks.
- Polish with kimwipes.
- Cuvettes must be stored in a clean dust-free environment.

4. MAINTENANCE

Source lamp may be replaced as follows:

- Remove the instrument case per manufacturer instruction.
- Remove the bulb by loosening a screw and removing the electrical leads.
- Insert the new bulb and reconnect the electrical leads.
- Before tightening the screw, be sure to position the filament so that it will be parallel to the axis of the sample well.
- Insert the lamp alignment tool in the sample well to focus the new bulb.
- Move the lamp bracket assembly in or out until a focused image of the filament is within the rectangular box on the lamp alignment tool.
- Once the filament image has been aligned and focused within the rectangular box on the lamp adjustment tool, tighten all screws snugly.
- Replace the instrument case.

5. PRECAUTIONS

Handle the reference standard or sample cuvettes by the top to prevent surface scratches or finger smudges which will cause analysis errors.

Check the mechanical meter zero when the instrument is in a vertical position and the power switch is off. Adjust to zero only if necessary by means of the black screw on the meter face.

The turbidity meter should be left on for the entire work shift to minimize warm-up and recalibration delays.

Do not leave the reference standard or filled cuvette in the sample well for long periods.

Leave the light shield in place on the instrument when it is not in use in order to protect the sample well for long periods.

Always set the range switch to 1000 range before turning the instrument on and whenever the light shield is not in place over the well.

6. REFERENCES

Manufacturer's Manual.



**Standard Operating Procedure No. 037
for
Dissolved Oxygen Measurements
(YSI Model 57)**

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the dissolved oxygen (DO) of all types of aqueous solutions, including drinking water, saline water, and industrial and domestic wastes. DO is a measurement of the amount of soluble oxygen in an aqueous solution. It is a general indication of an aerobic/anaerobic condition of a water sample.

Use of brand names in this SOP is not intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc. are acceptable. If alternate equipment is to be used, the contractor will provide applicable and comparable SOPs for the maintenance and calibration of same.

2. MATERIALS

The following materials may be required:

DO meter (YSI Model 57 or equivalent)
Self-stirring biological oxygen demand bottle probe
Membrane standards
Biological oxygen demand bottle

3. PROCEDURE

3.1 SETUP

It is important that before the meter is prepared for use and calibrated, it should be placed in the intended operating position, i.e., vertical, tilted, or horizontal. The instrument may need readjustment if the operating position is altered. The setup procedures should be as follows:

- With the switch set to **OFF**, adjust the meter pointer to zero with the screw in the center of the meter panel.
- Switch to **RED LINE** and adjust the **RED LINE** knob until the meter needle aligns with the red mark if necessary.
- Switch to **ZERO** and adjust to 0 mg/L scale with the **ZERO** control knob.
- Attach the prepared probe to the **PROBE** connector of the instrument and adjust the retaining ring finger tight.
- Before calibrating, allow 15 minutes for optimum probe stabilization. Repolarize whenever the instrument has been **OFF** or the probe has been disconnected.

3.2 CALIBRATION

Calibration is accomplished by exposing the probe to a known oxygen concentration, such as water-saturated air (%), or water of a known oxygen content (mg/L), and then adjusting the calibration controls so the display shows a reading matching the oxygen concentration of the known sample. Calibration can be disturbed by physical shock, touching the membrane, and fouling of the membrane or drying out of the electrolyte. Calibration will be checked after each series of measurements. Calibration of the DO meter will be performed on a daily basis as follows:

1. Place the probe in moist air. Biological oxygen demand probes can be placed in partially filled (50 ml) biological oxygen demand bottles. Wait 10 minutes for temperature to stabilize $\pm 2^{\circ}\text{C}$.
2. Switch to **TEMPERATURE** and read. Refer to Table SOP037-1 for solubility of oxygen in fresh water (calibration value).
3. Determine altitude or atmospheric correction factor from Table SOP037-2.
4. Multiply the calibration value from Table SOP037-1 by the correction factor from Table SOP037-2 to obtain the correct calibration value.

EXAMPLE: Assume a temperature of 20°C and an altitude of 1,100 ft. From Table SOP037-1, the calibration value of 20°C is 9.09 mg/L. From Table SOP037-2, the correction factor for 1,100 ft is 0.96. Therefore, the corrected calibration value is $9.09 \text{ mg/L} \times 0.96 = 8.73 \text{ mg/L}$.

5. Switch to the appropriate mg/L range, set the **SALINITY** knob to zero and adjust the **CALIBRATE** knob until the meter reads the calibration value from Step 4. Wait 2 minutes to verify calibration stability. Readjust if necessary.

3.3 DISSOLVED OXYGEN MEASUREMENT

- With the instrument prepared for use and the probe calibrated, place the probe in the sample.
- Turn the **STIRRER** knob **ON**.
- Adjust the **SALINITY** knob to the salinity of the sample if appropriate.
- Allow sufficient time for the probe to equilibrate to the sample temperature and DO.
- Read DO on appropriate scale.

- Before measuring the DO of the next sample, rinse probe and sample bottle with distilled water and then with next water sample.

Follow steps above for the next sample(s).

The DO meter should normally be left on during the working day to avoid the delay of waiting for probe repolarization.

4. MAINTENANCE

The following steps will be taken to maintain the DO meter:

- Replace the batteries when the **RED LINE** knob is at its extreme adjustment or at least annually.
- In the **BATT CHECK** position on the **STIRRER** knob, the voltage of the stirrer batteries is displayed on the red **0-10** scale. Do not permit them to discharge below 6 volts.
- Replace membrane every 2 weeks depending on application. Probes will be stored in a humid environment to prevent drying out.

5. PRECAUTIONS

The DO meter case is water resistant when properly closed. As a precaution against damaged gaskets or loose fittings, the instrument case will be opened and inspected for moisture whenever the instrument has been subjected to immersion or heavy spray. The case is opened by removing the screws on the rear cover and lifting the cover off.

6. REFERENCES

Manufacturer's handbook.

**TABLE SOP037-1 SOLUBILITY OF OXYGEN IN WATER EXPOSED TO WATER
SATURATED AIR AT 760 mm Hg PRESSURE**

Temperature (°C)	Solubility (mg/L)	Temperature (°C)	Solubility (mg/L)	Temperature (°C)	Solubility (mg/L)
0	14.62	17	9.67	34	7.07
1	14.22	18	9.47	35	7.95
2	13.83	19	9.28	36	7.84
3	13.46	20	9.09	37	6.73
4	13.11	21	8.92	38	6.62
5	12.77	22	8.74	39	6.52
6	12.45	23	8.58	40	6.41
7	12.14	24	8.42	41	6.31
8	11.84	25	8.26	42	6.21
9	11.56	26	8.11	43	6.12
10	11.29	27	7.97	44	6.02
11	11.03	28	7.83	45	5.95
12	10.78	29	7.69	46	5.84
13	10.54	30	7.56	47	5.74
14	10.31	31	7.43	48	5.65
15	10.08	32	7.31	49	5.56
16	9.87	33	7.18	50	5.47
NOTE: Derived from 17 th Edition, Standard Methods for the Examination of Water and Wastewater.					

**TABLE SOP037-2 CALIBRATION VALUES FOR VARIOUS
ATMOSPHERIC PRESSURES AND ALTITUDES**

Pressure			Altitude in		Calibration Value(%)
in. Hg	mm Hg	kPa	feet	meter	
30.23	768	102.3	-276	-84	101
29.92	760	101.3	0	0	100
29.61	752	100.3	278	85	99
29.33	745	99.3	558	170	98
29.02	737	98.3	841	256	97
28.74	730	97.3	1126	343	96
28.43	722	96.3	1413	431	95
28.11	714	95.3	1703	519	94
27.83	707	94.2	1995	608	93
27.52	699	93.2	2290	698	92
27.24	692	92.2	2587	789	91
26.93	684	91.2	2887	880	90
26.61	676	90.2	3190	972	89
26.34	669	89.2	3496	1066	88
26.02	661	88.2	3804	1160	87
25.75	654	87.1	4115	1254	86
25.43	646	86.1	4430	1350	85
25.12	638	85.1	4747	1447	84
24.84	631	84.1	5067	1544	83
24.53	623	83.1	5391	1643	82
24.25	616	82.1	5717	1743	81
23.94	608	81.1	6047	1843	80
23.62	600	80.0	6381	1945	79
23.35	593	79.0	6717	2047	78
23.03	585	78.0	7058	2151	77
22.76	578	77.0	7401	2256	76
22.44	570	76.0	7749	2362	75
22.13	562	75.0	8100	2469	74
21.85	555	74.0	8455	2577	73
21.54	547	73.0	8815	2687	72
21.26	540	71.9	9178	2797	71
20.94	532	70.9	9545	2909	70
20.63	524	69.9	9917	3023	69
20.35	517	68.9	10293	3137	68
20.04	509	67.9	10673	3253	67
19.76	502	66.9	11058	3371	66
NOTE: Derived from 17 th Edition, Standard Methods for the Examination of Water and Wastewater.					



Standard Operating Procedure No. 038 for Redox Potential Measurements

Prepared by

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to delineate protocols for measuring the redox of flooded sediment and soil. Redox is an indication of the reduction of oxidation intensity of an anaerobic system. Redox will be expressed in mV. A complete anaerobic system redox potential is -150 Mv. A positive value indicates an aerobic system.

Redox measurement in a natural system is difficult to obtain due to the absence of true equilibria, heterogeneity of media, and pH effects deprived redox measurements in natural media of precise thermodynamic significance (Ponnamperuma 1972). Despite the difficulties involved in the redox measurements in natural media, it is widely accepted that redox readings in natural anaerobic systems can provide valuable environmental information. Whitfield found redox useful as a semi-quantitative indicator of the degree of stagnation of a particular aquatic environment as did Ponnamperuma for flooded soils and sediments. The redox measurements of natural waters are not representative of that median, since natural waters are in a highly dynamic state rather than in or near equilibrium, according to Stumm and Morgan 1970. It is generally recognized that redox measurements in oxygenated natural waters are invalid.

2. MATERIALS

The following materials may be required:

pH meter	Sample bottle
Combination pH electrode	Standard solution (pH 4 and 7 buffers saturated with quinhydrone)
Lint-free laboratory wipes (Kimwipes, or equivalent)	Wash bottle
Distilled water	

3. PROCEDURE

Calibration of the pH meter will be calibrated on a daily basis as follows.

- Prepare beaker of standard solution with known voltage(s)
- Connect electrodes to instrument
- Turn on and clear
- Rinse electrode with distilled water blot excess with laboratory wipes
- Immerse probe in beaker of standard solution
- Press mV key
- After the reading stabilizes, the absolute mV of solution is displayed.
- Rinse electrode and blot excess.

Redox will be measured after calibration as follows:

- Prepare sample in a beaker
- Rinse electrode and blot excess water
- Immerse electrode in sample and stir briefly
- Press mV switch
- Record the reading after it stabilizes
- For next sample(s), follow above steps.

4. MAINTENANCE

Check the batteries each time the meter is used.

Keep the probe stored in a 0.1 M KCL solution when not in use. Alternatively, the electrode may be rinsed with deionized water and trapping any residual water inside the protective cap.

5. PRECAUTION

Remove coatings of oil material or particulate matter that can impair electrode response by gentle wiping or detergent washing, followed by distilled water rinsing.

6. REFERENCES

Beckman Instruments, Inc. User Manual for 10, 11, and 12 pH/ISE meter.

Ponnamperuma, F.N. 1972. The Chemistry of Submerged Soils, Advances in Agronomy. Vol. 24.

Stumm, W. and J.J. Morgan. 1970. Aquatic Chemistry, Wiley, New York.

Whitfield, M. 1969. Eh as an Operational Parameter in Estuarine Studies. *Limnol. Oceanogr.*, Vol. 14.



Standard Operating Procedure No. 039 for Sample Preservation and Container Requirements

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1. PURPOSE AND SCOPE

The purpose of this Standard Operating Procedure (SOP) is to define the preservatives and techniques to be employed in preserving environmental samples between collection and analysis.

2. MATERIALS

The following materials may be required:

Containers (see Section 3 for description)	NaOH
HNO ₃	Ice chests
H ₂ SO ₄	Ice

3. DEFINITION OF CONTAINER TYPES

- Type A** **Container:** 80 oz amber glass, ring handle bottle/jug, 38-mm neck finish.
Closure: White polypropylene or black phenolic, baked polyethylene cap, 38-430 size, 0.015-mm polytetrafluoroethylene (PTFE) liner.
- Type B** **Container:** 40-mL glass vial, 24-mm neck finish
Closure: White polypropylene or black phenolic, open top, screw cap, 15-mm opening, 24-400 size.
Septum: 24-mm disc of 0.005-in PTFE bonded to 0.120-in. silicon for total thickness of 0.125-in.
- Type C** **Container:** 1-L high density polyethylene, cylinder-round bottle, 28-mm neck finish.
Closure: White polyethylene cap, white ribbed, 28-410 size; F217 polyethylene liner.
- Type D** **Container:** 120-mL wide mouth glass vial, 48-mm neck finish.
Closure: White polyethylene cap, 40-480 size; 0.015-mm PTFE liner.
- Type E** **Container:** 250-mL boston round glass bottle
Closure: White polypropylene or black phenolic, open top, screw cap.
Septum: Disc of 0.005-in PTFE bonded to 0.120-in silicon for total thickness of 0.125-in.

- Type F** **Container:** 8-oz short, wide mouth, straight-sided, flint glass jar, 70-mm neck finish.
Closure: White polypropylene or black phenolic, baked polyethylene cap, 48-400 size; 0.030-mm PTFE liner.
- Type G** **Container:** 4-oz tall, wide mouth, straight -sided, flint glass jar, 48-mm neck finish.
Closure: White polypropylene or black phenolic, baked polyethylene cap, 48-400 size; 0.015-mm PTFE liner.
- Type H** **Container:** 1-L amber, Boston round, glass bottle, 33-mm pour-out neck finish.
Closure: White polypropylene or black phenolic, baked polyethylene cap, 33-430 size; 0.015-mm PTFE liner.
- Type K** **Container:** 4-L amber glass ring handle bottle/jug, 38-mm neck finish.
Closure: White polypropylene or black phenolic, baked polyethylene cap, 38-430 size; 0.015-mm PTFE liner.
- Type L** **Container:** 500-mL high-density polyethylene, cylinder bottle, 28-mm neck finish.
Closure: White polypropylene, white ribbed, 28-410 size; F217 polyethylene liner.

4. PROCEDURE

All containers must be certified clean, with copies of laboratory certification furnished upon request.

Water samples will be collected into pre-preserved containers appropriate to the intended analyte as given in Quality Assurance Project Plan. Samples taken for volatile organic compounds will be collected in accordance with SOP No. 003, Section 3.3.8. Samples taken for metals analysis will be verified in the field to a pH <2. The container should be tightly capped, then swirled to thoroughly mix the sample. The cap will then be loosened to release any excess pressure this operation may have generated. Samples taken for total phosphorous content will be verified in the field to a pH <2. The container should be tightly capped and swirled to thoroughly mix the sample. The cap will then be loosened to release any excess pressure this operation may have generated. Samples taken for cyanide will be verified for a pH >12. No preservatives will be added to any other water samples. These samples will be immediately placed on ice and cooled to 4°C.

Soil and sediment samples will be collected into containers appropriate to the intended analyte as given in the Quality Assurance Project Plan. Samples taken for volatile organic compound analysis will be collected in accordance with the site-specific SOP. Samples taken for metals

analysis will be tightly capped, placed on ice, and maintained at a temperature of 4°C. Samples taken for total phosphorous content will be tightly capped, placed on ice, and maintained at a temperature of 4°C. Samples taken for cyanide will be alkalized to a pH > 12 by the addition of NaOH. No preservatives will be added to any other soil samples. These samples will be immediately placed on ice and cooled to 4°C.

5. MAINTENANCE

Not applicable.

6. PRECAUTIONS

Note that acidifying a sample containing cyanide may liberate HCN gas.

- Avoid breathing any fumes emanating from acidified samples.
- Acidify samples only in the open, rather than in closed spaces such as a vehicle.
- Hold suspected HCN-generating sample away from body and downwind while manipulating it.
- See the Health and Safety Plan for other safety measures

7. REFERENCES

U.S. Environmental Protection Agency (U.S. EPA). 1986. Test Methods for Evaluating Solid Waste, SW-845.

U.S. EPA. 1987. A Compendium of Superfund Field Operations Methods, EPA 540-P87-001.

U.S. EPA. 1991. A Compendium of ERT Soil Sampling and Surface Geophysics Procedures.



Standard Operating Procedure No. 042 for Disposal of Investigation-Derived Material

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure is to define the required steps for disposing of investigation-derived material (IDM) generated during field activities.

IDM, as used herein, includes soil cuttings, drilling muds, purged groundwater, decontamination fluids, and disposable personal protective equipment. For the sake of clarity and ease in use, this Standard Operating Procedure is subdivided into procedures for disposal of liquid IDM and solid IDM as follows:

- Liquid IDM (Section 3.2) includes the following materials:
 - Water from initial development of new wells and the redevelopment of existing wells.
 - Purge water from groundwater sampling.
 - Decontamination fluids (Section 3.4)
- Solid IDM (Section 3.3) consists of the following materials:
 - Drill cuttings from monitoring well installation
 - Grout, a mixture of cement and bentonite, generated during installation of monitoring wells
 - Disposable personal protective equipment (Section 3.4).

2. MATERIALS

The following materials may be required:

Any additional equipment that may be dictated by project or site-specific plans	Hazardous waste labels
Bar codes	Permanent marker
Chain-of-custody forms	Field Logbook (bound)
Department of Transportation 17C spec. metal containers	Waste identification labels

3. PROCEDURE

3.1 GENERAL

No container will be labeled as a “Hazardous Waste” unless the contents are in fact known to be hazardous as defined by 40 CFR 261.

IDM may be disposed onsite if it is: (1) initially screened, or evaluated to determine whether it is contaminated; (2) not abandoned in an environmentally unsound manner; and (3) not inherently waste-like.

IDM are to be considered contaminated if they: (1) are visually or grossly contaminated, (2) have activated any field monitoring device which indicates that the level exceeds standard Level 1, (3) have previously been found to exhibit levels of contamination above environmental quality standards, and (4) the responsible party and/or appropriate regulator deem(s) that records of historical uses indicate that additional testing of the IDM is needed, or additional caution is warranted handling IDM from a given site.

3.2 PROCEDURES FOR LIQUID INVESTIGATION-DERIVED MATERIAL DISPOSAL

1. All water from initial development of new wells, and purge water generated during the first round of groundwater sampling will be containerized in Department of Transportation approved 55-gal drums. Decontamination fluids may be bulk-containerized until completion of field task.
2. Label all containers as to type of media, the date the container was sealed, the point-of-generation, and the points-of-contact. The well number and container number will be identified on the container.
3. The contractor/support personnel will log all media generated onsite into a bound Field Logbook. Media information should include the following: the date of generation, contents of containers, the number of containers with the same contents (if applicable), location of containers, the well number the media is associated with, personnel sampling the media, sampling dates, and sampling results.
4. Containers of well development water and purge water may be stored at the well site pending first round analytical results.
5. Laboratory turnaround time must be no greater than 30 days. Upon receipt of the analytical results, a copy will be furnished to the client within 3 working days. Both the client and contractor will evaluate the data to determine disposal requirements, per state and local regulations. A disposal decision is required within 10 days of receipt of sampling results. Appropriate disposal must be performed no later than 50 days from the decision date unless prevented by inclement weather (e.g., rain and muddy conditions may preclude site access, freezing weather may freeze media).

-
1. This value is defined as two times background, where “background” values are to be determined as follows: (1) regional background values will be used where they are available; and (2) if regional values are not available, background may be empirically determined at uncontaminated sampling sites using onsite sensors such as organic vapor analyzers (photoionization detector or flame ionization detector), scintillometers, etc.

Dispose of non-hazardous media in accordance with Step 6 et seq. through 8 et seq. of this procedure.

Dispose of hazardous waste in accordance with Step 9 et seq. of this procedure.

6. If the first round analytical data of the liquid media is below the Maximum Contaminant Levels established by the Federal Safe Drinking Water Act, the water may be gradually infiltrated into the ground at least 50 ft downgradient of the well.

If the well location has no downgradient area, the water will be infiltrated into the ground in an area deemed appropriate by the client and the contractor/support personnel.

Disposal locations must allow percolation of the water and prohibit “ponding.”

Upon completion of water discharge to ground, enter type of media, amount of media, date of disposal, and discharge point(s) in a bound Field Logbook and provide this information to the client.

Empty containers are to be properly decontaminated, stored, and reused by the appropriate personnel.

If the liquid media sampling results do not meet the required Maximum Contaminant Levels and cannot be discharged to the ground, then determine if the waste meets the sanitary sewer discharge criteria (National Pollutant Discharge Elimination System standards).

7. If at any time visual contamination of purge/development water is observed, or if organic vapor monitor readings (HNu, photoionization detector) register more than 5 ppm above background and/or rad meters register more than twice the background mrem, then the liquid will be drummed and a composite sample will be taken that day. A disposal decision will be based on the analytical results of this sample rather than the first round of analytical results.

3.3 PROCEDURE FOR SOLID INVESTIGATION-DERIVED MATERIAL DISPOSAL

1. If the conditions outlined in Section 3.1 are met, proceed to Section 3.3, Step 2; otherwise, go to Section 3.3, Step 7.
2. During drilling operations, the resulting cuttings and mud will be discharged onto the ground near the well if the following conditions are met: (1) no visual contamination is observed, (2) organic vapors are less than 5 ppm above background, (3) rad meter readings (if applicable) are under two times background, and (4) if the potential for metals contamination exists, the medium has been screened and found to be less than two times background.

Proper sediment and erosion control measures will be implemented as follows:

- Drill cuttings will be uniformly spread and contoured to blend with the surroundings of the site.
 - If amount of solid IDM exceeds 5,000 ft² or 100 yd³ of material, a Sediment and Erosion Control Plan is required.
 - If the amount of solid IDM is under 5,000 ft² or 100 yd³, the site will be stabilized as soon as possible. Stabilization includes mulch, seed, and tack.
 - Critical areas require stabilization within 7 days from the date of well completion. Critical areas include swales, water sources, drainage ditches, etc.
 - All other disturbed areas require stabilization within 14 days from the date of well completion.
3. If the well location is in or near a wetland, the drill cuttings will be drummed and transported away from the site for spreading.
 4. Label all IDM containers that will not be spread on the day of generation. Each container should be labeled with the type of media, the date the container was sealed, the point-of-generation, and the name of the contact person. The well number and container number should be identified on the container.
 5. The contractor/support personnel will log all media generated onsite into a bound Field Logbook. Media information should include: the date of generation, contents in containers, the number of containers with the same contents, location of containers, and the well number the media is associated with.
 6. Containers will be staged at the well site until contractor/support personnel spread the cuttings in the appropriate locations, using proper sediment and erosion control measures per Section 3.3 et seq.
 7. If drilling mud and cuttings show visible contamination, or organic vapor readings are more than 5 ppm above background levels, or rad meter readings (if applicable) show greater than two times background levels, media will immediately be containerized, labeled appropriately (Section 3.2), and sampled on the same day.
 8. The solid IDM should be sampled and appropriate Toxicity Characteristic Leaching Procedure analyses conducted prior to determining disposition. Laboratory turn-around time must be no greater than 30 days. Upon receipt of analytical results, a copy will be furnished to the client within 3 working days. The contractor will evaluate the data to determine disposal requirements within 10 days. Appropriate disposal must be performed no later than 50 days after the decision date if weather permits (Section 3.2).

- If the solid IDM are determined to be non-hazardous and uncontaminated, go to Section 3.3.
 - If the solid IDM are determined to be non-hazardous but contaminated , go to Section 3.3.
 - If the solid IDM are found to be hazardous wastes, go to Section 3.3.
9. If the solid IDM are not a hazardous waste **and** analytical data shows contaminant concentrations below the U.S. Environmental Protection Agency Region 3 (or applicable Region where work is being performed) Risk-Based Concentrations, contact the appropriate federal, state, or local agency for approval to discharge onto the ground near the site of generation.
- Follow steps detailed in Section 3.3, Step 2 et seq. (above) pertaining to sediment and erosion control.
 - Upon completion of the solid IDM discharge to the ground, enter type of media, amount of media, date of disposal, and discharge point(s) in a bound Field Logbook. This information must be provided to the client.
 - Empty containers are to be properly decontaminated, stored and reused by appropriate personnel.
10. If the intrusive media is not a hazardous waste but analytical data shows concentrations above the screening criteria, dispose of the IDM according to state and local regulations.
- Ensure that the waste containers are properly labeled as applicable in accordance with Section 3.3, Step 4.
 - Inform the client of the type and amount of waste, and the location of the waste.
 - When the waste is removed, enter the type of waste, amount of waste, date of pickup, and the destination of the waste in a bound Field Logbook. This information must be provided to the client.

3.4 PROCEDURES FOR DECONTAMINATION SOLUTION AND PERSONAL PROTECTIVE EQUIPMENT DISPOSAL

Decontamination solutions include catch water from steam-cleaning operations performed on large sampling equipment, drill rigs, and drums, as well as smaller quantities of soapy water and rinse solutions used in decontaminating field sampling equipment. At the completion of the field event, a composite sample of the decontamination solution will be taken. The decontamination solution will be treated as liquid IDM pending results (Section 3.2 et seq.).

Personal protective equipment will be containerized onsite, appropriately labeled, and disposed of in a designated trash receptacle.

4. MAINTENANCE

Not applicable.

5. REFERENCES

Environment Article Section 7-201(t).

U.S. Environmental Protection Agency. 1991. Management of Investigation-Derived Wastes during Site Inspections PB91-921331, OERR Directive 9345.3-02. Office of Emergency and Remedial Response U.S. Environmental Protection Agency, Washington, D.C. May.



**Standard Operating Procedure No. 044
for
Assessment of Existing Wells Using
Downhole Geophysics**

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1. SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to establish protocol for using downhole surveys to evaluate the integrity of older, existing wells at the site for which details of construction are not known. Numerous wells exist within the remedial investigation study area which predate the current remedial investigation efforts. Some of these wells were installed in locations which might yield valuable data. Unfortunately, construction records for these wells are frequently incomplete or missing. If the wells could be determined to be sufficient quality, they could be sampled, and the cost of installing new wells (possibly in less than optimal locations due to the exclusion zones mandated in SOP No. 019) would be avoided.

Selected downhole geophysical techniques could prove effective in determining the integrity of these older wells. This SOP describes four techniques: natural gamma logs, caliper logs, sonic logs, and downhole video camera, which, employed individually or together should yield data about well construction and/or integrity. These data can then be factored into the decision to use or replace the well.

2. MATERIALS

The following materials may be required:

Sonde(s) for gamma log and/or sonic log and/or caliper log and/or video camera	Field notebook
Associated hoisting mechanism(s)	Decontamination supplies (SOP No. 005)
Data logger(s)	Personal protective equipment as required by the contractor's Health and Safety Plan

3. PROCEDURE

The specific procedure for each logging technique will be detailed in the manufacturer's manuals and specifications sheets for a given instrument. Rather than attempt to cover these specific procedures, this SOP will characterize and describe the instruments, and the type and applications for the data each will yield.

The following steps are general procedures which must be followed regardless of the instrument:

- Become thoroughly acquainted with the manufacturer's manual.
- Review the procedures outlined therein with an experienced operator to verify that all procedures are understood.
- Just prior to testing, as part of the safety briefing, review instrument procedures.

- Record the well location, site characteristics, sketch map(s), and other pertinent data in the field logbook.
- Perform all steps in SOP No. 010 and note the readings in the field logbook.¹
- Lower instrument(s) into hole. Use centralizers set to the hole diameter as needed to ensure the instrument(s) is/are centered, and run smoothly in the hole.
- Run test(s) in well. Multiple runs may be required to optimize data quality.
- If broken or missing well casing is encountered, the instrument(s) should not be advanced past the broken section. There is a danger of losing the instrument in the hole due to lodging and/or cave-in, and the broken casing (or screen) would preclude using that well for sampling in any case.
- Attach a wiper to the cable when withdrawing the instrument(s) to remove excess moisture from the cable. Decontaminate all downhole equipment before insertion and after use according to SOP No. 005.
- Review the data and procedures with the experienced operator to determine where refinement of technique may be required.
- Final data interpretation should be performed by experienced personnel.

3.1 GAMMA LOG

The gamma log is also called the natural gamma, gamma ray, or radioactivity log. This instrument measures the naturally occurring radioactivity in the geologic materials found in the borehole. Clays and clay-rich soils tend to be gamma emitters. Gamma particles are very active and can easily penetrate the well casing, thereby making this a good tool for determining stratigraphy.

3.2 SONIC LOG

Sonic logs, also called continuous velocity logs, rely on emitted pulses of sound which impinge upon the borehole walls and traverse the wall materials to one or more receivers which are mounted at known distances from the emitter. By comparing the travel time (velocity) and signal strength of the return signal, one can determine the relative densities of the wall materials. Cement and grout are more dense and, therefore, have higher velocities than do soil, voids and filter pack materials. This means that sonic logging is an excellent tool for determining the

1. Note that non-aqueous phase liquids may foul some instruments. Video cameras are particularly sensitive to lens fouling by light non-aqueous phase liquids. If non-aqueous phase liquids are found in the hole, use of downhole video may be omitted. If used, do not coat the lens with detergent, as recommended by some manufacturers, as this would introduce further contaminants into the hole.

integrity of the grout seal around the hole. The following table provides typical travel times for various materials:

Material	Sonic Velocity (ft/sec)	Transit Time (sec/ft)
Oil	4,300	232
Water	5,000-5,300	200-189
Neoprene	5,300	189
Shale	6,000-16,000	167-62.5
Rock salt	15,000	66.7
Sandstone	Up to 18,000	55.6
Anhydrite	20,000	50.0
Limestone (carbonates)	21,000-23,000	47.6-43.5
Dolomites	24,000	42

3.3 CALIPER LOG

Caliper logs use a set of spring calipers to make mechanical contact with the walls of the borehole or casing and provide a very sensitive means to determine the hole diameter, and to some extent, the roughness of the borehole or casing walls. A caliper log can often detect each joint in the well casing and will accurately locate the depth and length of the well screen(s).

3.4 DOWNHOLE VIDEO CAMERA

The downhole video camera is the only technique which gives the investigator a firsthand look at the borehole and/or well casing walls. In addition to the procedures outlined above in Section 3, before inserting the video camera, slowly pan the camera around the site to photographically record the site features. Also, if the recorder has voice recording capabilities, a commentary of the field operator's onsite interpretation of the scene should be recorded as the survey is run. Downhole, the camera may be stopped for additional commentary, detailed examination of a feature, and/or still photography.

If multiple lens capabilities are available, the downhole video should be run first with a forward-looking lens, to determine hole conditions, then with an off-axis (e.g., right angle) lens to record sidewall details.

4. MAINTENANCE

See manufacturer's manuals.

5. PRECAUTIONS

All wells should be considered contaminated unless proven otherwise. Appropriate personal protective equipment must be worn.

All safety checks required in SOP No. 010 must be performed.

As with any intrusive technique, each instrument must be properly decontaminated before and after each use. See SOP No. 005 for details.

6. REFERENCES

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Standard Operating Procedure No. 047

Direct-Push Technology Sampling

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1. SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) establishes the protocol for using direct-push technology (DPT) in media sampling and performing subsurface characterization. This SOP includes the following DPT methods: Geoprobe[®], Hydropunch[®], Cone Penetrometer Testing (CPT), and Site Characterization and Analysis Penetrometer System (SCAPS).

2. MATERIALS

The following materials may be required:

Appropriately sized, all-terrain vehicle-skid-or track-mounted; DPT equipment; and supplies (i.e., hydraulic derrick and hammer assembly)	Personal protective equipment
Bentonite grout and clean sand for DPT hole abandonment	Phosphate-free, laboratory-grade detergent (e.g., Liquinox, Alconox, etc.)
DPT stainless steel rods	Source of approved water
Heavy plastic sheeting	Steam cleaner/sprayer and water obtained from approved source for decontaminating DPT equipment
Logbook	Steel drums for intrusion derived wastes (e.g., contaminated personal protective equipment, decon solutions, etc.)
Long-handled bristle brushes	Wash and rinse tubs
Mini-bailer or tubing and peristaltic pump (groundwater sampling only)	

3. GEOPROBE[®] AND HYDROPUNCH[®]

3.1 MATERIALS

Water sources for Geoprobe[®] and Hydropunch[®] activities, grouting, sealing, filter placement, well installation, and equipment decontamination must be approved by the Project Manager prior to arrival of the Geoprobe[®] and Hydropunch[®] equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the Geoprobe[®] and Hydropunch[®] equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

3.2 GROUNDWATER – HYDRAULIC PUSHING AND SAMPLING

The objective of the selected DPT sampling technique is to allow grab samples to be taken at a selected site to facilitate aquifer characterization and analysis of potential contaminants. The analytical results from sampling can also be used to determine the placement of monitoring wells.

A site geologist will be present during all sampling and installation procedures, and will fully document all procedures and soil characteristics in the Field Logbook. Refer to SOP No. 003 (Field Logbook).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Work Plan, a hand lens (10X), a standard color chart, and a grain size chart.

Only solid vegetable shortening (e.g., Crisco®) without flavoring or additives may be used on downhole Geoprobe® and Hydropunch® equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after DPT activities.

The subcontractor will use the equipment specific guidelines for installation of the Geoprobe® DPT equipment. Probe rods will be forced into the ground by hydraulic means.

- Drive the sampler to the desired groundwater sampling interval. At the desired depth, insert extension rods down the inside diameter of the probe rods until the extension reaches the bottom of the screen. Remove the probe rods and sampler sheath while holding the screen in place.
- Collect the groundwater sample in the screen interval with a mini-bailer, peristaltic or vacuum pump, or other acceptable small diameter sampling device.
- The head of the rod may be equipped with a sensing device for characterization of soil properties or the contaminant content.

The subcontractor will use the equipment-specific guidelines for installation of the Hydropunch® equipment. Rods will be forced into the ground by hydraulic means.

- The Hydropunch® tool is a double cylinder, designed to be sealed until the desired sampling depth is reached. Upon reaching the desired sampling depth, the outer cylinder is pulled back, exposing a perforated, stainless steel sampling barrel covered with filter material.

- The water sample enters the barrel and the sample is retrieved by pulling the probe rods from the hole with the hydraulic derrick and hammer assembly. Groundwater is the only media that is sampled by Hydropunch[®] equipment.
- The head of the rod may be equipped with a sensing device for characterization of the soil properties or the contaminant content.
- The sample volume collected with this technique is approximately 500-1,000 ml. Larger sample volumes can be collected by inserting tubing attached to a peristaltic pump into the rods to obtain water samples.

If desired, a small diameter monitoring well may be installed at this point. Refer to SOP No. 019 (Monitoring Well Installation).

If a well will not be installed, the rods will be removed as the borehole is simultaneously filled with a bentonite/grout mixture. A polyvinyl chloride (PVC) tube fed into the rod casing will allow the addition of grout.

3.3 SUBSURFACE SOIL – HYDRAULIC PUSHING AND SAMPLING

The objective of the selected DPT sampling technique is to allow grab samples to be taken at a selected site for characterization of the stratigraphy and for analysis of potential contaminants. The analytical results from sampling can also be used to determine the placement of monitoring wells.

A site geologist will be present during all DPT sampling and soil characterization. All procedures and soil characteristics will be fully documented in the Field Logbook (refer to SOP No. 003 [Field Logbook]).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Plan, a hand lens (10X), a standard color chart, and a grain-size chart.

Only solid vegetable shortening (e.g., Crisco[®]) without flavoring or additives may be used on downhole Geoprobe[®] equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after DPT activities.

The subcontractor will use the equipment specific guidelines for installation of the Geoprobe[®] DPT equipment. Probe rods will be forced into the ground by hydraulic means. Additional rods will be added in 3- to 4-ft increments until the leading edge of the sampler reaches the top of the desired sampling interval.

Once the desired sampling depth has been reached, insert extension rods down the inside diameter of the probe rods until it reaches the top of the sampler assembly. Attach the extension rod handle to

the top extension rod. Turn the handle clockwise until the stop-pin detaches from the drive head. Remove the extension rods and the stop-pin. Attach a drive cap to the probe and drive the sampler approximately 2 ft using hydraulic derrick.

The DPT sampler can be retrieved by pulling the probe rods from the hole with the hydraulic derrick and hammer assembly.

The liner will be capped with Teflon[®] tape and vinyl end caps. The liners can be split open to remove samples for composition analysis or for transfer to other containers for shipment to the laboratory for analysis.

The head of the rod may be equipped with a sensing device for characterization of the soil properties or the contaminant content.

3.4 DECONTAMINATION

All Geoprobe[®] and Hydropunch[®] DPT equipment must be thoroughly cleaned before and after each use to allow retrieval of representative groundwater samples. Geoprobe[®] soil sample liners are disposed of after each use. Scrub all metal parts with a stiff, long bristle brush and a non-phosphate soap solution. Steam cleaning may be substituted where available. Rinse with distilled water and allow to air-dry before assembly.

After decontamination, a new clean liner will be installed and all parts will be inspected for wear or damage.

Refer to SOP No. 005 (Decontamination).

3.5 ABANDONMENT

Pure bentonite or a bentonite/grout mixture (20:1) will be used to fill the resulting borehole if the water table is penetrated. Boreholes that do not penetrate the water table will be backfilled with cuttings from the hole and topped with a bentonite seal. Clean sand will be used to fill any remaining volume in the borehole.

Abandonment of Geoprobe[®] and Hydropunch[®] generated DPT boreholes will meet the standards established under SOP No. 028 (Well and Boring Abandonment).

4. CONE PENETROMETER TESTING

4.1 MATERIALS

A CPT rig typically consists of an enclosed 20- to 40-ton truck equipped with vertical hydraulic rams that are used to force a sensor probe into the ground. The weight of the CPT rig is dependent upon the thrust required at the site. The majority of CPT rigs are mounted in heavy-duty trucks that are ballasted to a total dead weight of approximately 15 tons. Screw anchors are utilized to develop the extra reaction to reach the maximum thrust of 20 tons. The rig is separated into two separate workspaces: data acquisition and hydraulic push areas.

Water sources for CPT activities and decontamination must be approved by the Project Manager prior to arrival of the CPT equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the DPT equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

4.2 SUBSURFACE CHARACTERIZATION

The objective of this technology is to collect stratigraphic information using CPT equipment to determine subsurface stratigraphy and geotechnical properties at a particular site. CPT activities will be in accordance with American Society for Testing and Materials D 3441-86 and American Society for Testing and Materials D 5778-95. The stratigraphic information gathered can be used to facilitate the selection of DPT sampling screen intervals. At the same time, it is possible to install a 0.25-in. diameter pre-packed PVC monitoring well.

CPT rods are used to hydraulically push the CPT probe into the subsurface. Probes cannot be pushed into hard rock, and significant gravel or cobble content in the formation may impede or preclude penetration of the probe. The depth of penetration achievable depends on the type of formation, type of sampling probe, and size of the hydraulic equipment used.

The CPT probe includes the following components:

- A conical tip to measure vertical resistance beneath the tip.
- A friction sleeve to measure frictional resistance on the side of the probe, as a function of depth.

- Two internal strain gauge-type load cells, which independently measure the vertical resistance and side friction.
- A cone pressure gauge to measure the water pressure as the probe is pushed into the ground.
- Inclinator to determine potential drifting of the probe (optional).
- Seismic transducers to perform downhole seismic surveys (optional). Therefore, stratigraphic data collected with the CPT include: tip resistance, local friction, friction ratio, pore pressure, and resistivity.

Data will be transferred from the probe to the data acquisition system or logger through an electrical cable. The hole will be advanced continuously at a rate of 0.6-1.0 in. per second. The data will be logged at every 0.4-0.8 in. of penetration. Monitor the probe's stratigraphic position will be monitored as it advances downward. Perform pore water pressure dissipation tests in representative hydrostratigraphic intervals. Record dissipated pore water pressures to represent hydraulic head values.

Once the confining unit underlying the surficial aquifer or the required depth has been reached, the CPT is pulled from the ground. Target interval samples can be collected during CPT hole advancement using direct push sampling techniques, i.e., Geoprobe[®] or Hydropunch[®] (Section 3).

4.3 DECONTAMINATION

All CPT equipment must be thoroughly cleaned before arrival at the work site, between test holes, and prior to being moved out of a work area. Scrub all metal parts with a stiff, long bristle brush and a non-phosphate soap solution. Steam cleaning may be substituted where available. Rinse with distilled water and allow to air-dry before assembly.

Refer to SOP No. 005 (Decontamination).

4.4 ABANDONMENT

If the push hole was developed for the stratigraphic test only, once the testing is completed, grout the hole from bottom to top. If the hole has not collapsed after removing the CPT, PVC piping will be used to grout the hole. If the hole has collapsed after removing the CPT, then hollow CPT rods and a sacrificial tip will be used to grout the hole. The PVC pipe or CPT rods will be pushed to the bottom of the hole. Grout will then be pumped to the bottom of the hole as the PVC pipe or CPT rods are withdrawn.

Refer to SOP No. 028 (Well and Boring Abandonment).

5. SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM

5.1 MATERIALS

SCAPS cone penetrometer and laser induced fluorescence (LIF) technology requires the use of a specialized 20-ton truck. The truck has two separate enclosed compartments. Each compartment is temperature controlled and monitored for air quality. The two rooms are the data acquisition and processing room, and the hydraulic ram/rod handling room. Approximately 20 ft of overhead clearance is required to fully extend the hydraulic ram and allow for leveling jack movement.

All materials required to complete SCAPS analysis are provided by the subcontractor to include cone penetrometer equipment. All hydraulic equipment, SCAPS rods, nitrogen lasers, etc. are included within the vehicle. A decontamination water source and a source of water for mixing the grout are required.

Water sources for equipment decontamination must be approved by the Project Manager prior to arrival of the SCAPS equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, cost per gallon (if applicable), dates and results associated with all available chemical analysis over the past 2 years, and the name and address of the analytical laboratory (if applicable).

Pure sodium bentonite with no additives will be the only additive allowed, and its use must be approved by the Project Manager prior to the arrival of the SCAPS equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product number, product description, and intended use for the product.

Portland Type II cement will be used for grout (refer to SOP No. 019).

5.2 HYDRAULIC PUSHING AND SAMPLING

The objective of the SCAPS technique is to allow grab samples and stratigraphic information to be collected at a selected site to facilitate subsurface characterization and for analysis of potential contaminants. The analytical results obtained can also be used to determine the placement of monitoring wells. At the same time, it is possible to install a small diameter well for sampling purposes. Refer to SOP No. 019 (Monitoring Well Installation). If a well will not be installed, the borehole can be grouted as the equipment is removed.

A site geologist will be present during all installation and sampling procedures and will fully document all procedures and soil characteristics in the Field Logbook (refer to SOP No. 003 [Field Logbook]).

The site geologist will have on hand, at a minimum, a copy of the approved Health and Safety Plan, this SOP, the Field Investigation Work Plan, a hand lens (10X), a standard color chart, and a grain-size chart.

Only solid vegetable shortening (e.g., Crisco®) without flavoring or additives may be used on downhole SCAPS equipment.

Surface runoff or other fluids will not be allowed to enter any DPT location or well during or after direct-push activities.

The subcontractor will use the equipment specific guidelines for installation of the SCAPS DPT equipment. Prior to SCAPS field activities, calibration soil samples will be collected and analyzed in order to determine the LIF sensor fluorescence threshold and detection limits for the site.

SCAPS LIF technology uses a pulsed nitrogen laser coupled with an optical detector to make fluorescence measurements via optical fibers. The LIF sensor is mounted on a cone penetrometer probe so that soil classification data and fluorescence data are collected simultaneously. The laser consumes nitrogen gas, which is supplied from cylinders stored on the accompanying trailer.

The SCAPS CPT sensors are used to gather stratigraphic information. See Section 4 for CPT operating procedures.

Target interval samples can be collected during SCAPS hole advancement using direct push sampling techniques such as Geoprobe® or Hydropunch® (Section 3).

5.3 DECONTAMINATION

Decontamination of SCAPS equipment is automated after initialization by a field team member. A pressurized hot water system is used to decontaminate the push rods as they are retracted from the ground. The SCAPS vehicle is equipped with a decontamination collar mounted to the bottom that cleans the rods. The decontamination water is removed by vacuum and transferred to a storage drum prior to disposal or treatment. A trailer attached to the back of the vehicle contains the water pump, heater for decontamination, and decontamination water containment drum.

Worker exposure is reduced by minimizing contact with contaminated media.

Refer to SOP No. 005 (Decontamination).

5.4 ABANDONMENT

SCAPS automatically grouts the penetrometer cavity as the rods are removed. The grout is pumped at high pressure through a 0.25-in. diameter tube in the center of the penetrometer rods. The tip is sacrificed at the bottom of the cavity to allow release of the grout.

A trailer attached to the back of the vehicle contains the 300-gal grout mixing bin and pump.

If the automatic grout feed does not work, the cavity will be manually filled with grout.

Abandonment of SCAPS generated borehole will meet the standards established under SOP No. 028 (Well and Boring Abandonment).

6. MAINTENANCE

Not applicable.

7. PRECAUTIONS

Refer to the site-specific Health and Safety Plan for discussion of hazards and preventive measures during intrusive activities.

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Standard Operating Procedure No. 048 for Low-Flow Sampling

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1. GROUNDWATER SAMPLING BY LOW-FLOW PURGE AND SAMPLING METHOD USING DEDICATED PUMPS

1.1 SCOPE OF APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to establish the protocol for collecting groundwater samples using dedicated pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity.

1.2 EQUIPMENT/MATERIALS

- Work Plan.
- Well construction data, location map, and field data from last sampling event.
- Field logbook and Field Record of Well Gauging, Purging, and Sampling forms (Figure SOP048-1).
- Electric water level measuring device, 0.01 ft accuracy for monitoring water level during pumping operations.
- Pumps: adjustable rate, submersible pumps constructed of stainless steel and Teflon®.
- Tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic analysis. For samples collected for inorganics analysis, Teflon or Teflon-lined polyethylene tubing will be used.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (generator, etc.).
- Water quality indicator parameter monitoring instruments—pH, turbidity, specific conductance, and temperature. Optional indicators—Eh and dissolved oxygen.
- Flow-through cell (preferred) or clean container for water quality probes.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.
- Drum for purge water containment.

1.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.
- Check well for damage or evidence of tampering, record pertinent observations in field logbook and sampling form.
- Lay out sheet of polyethylene for monitoring and sampling equipment.
- Unlock well and remove well cap (if applicable).
- Measure VOCs with an ionization detector (flame or photo) instrument at the rim of the well and in the breathing zone, and record the readings in the field logbook and the sampling form.
- Measure and record the height of protective casing above the concrete pad or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.
- Dedicated sampling pumps should be positioned with the pump intake mid-point in the screened interval. If non-dedicated equipment is used, care will be taken to position pump or sampling hose intake at the screen mid-point.
- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. If a reference point is made, it will be noted in the field logbook. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will be measured following the completion of sampling because of the potential to stir up sediment at the bottom of the well.
- Prepare the pump by checking electrical connections, discharge tubing, and motor (Grundfos Redi-Flo2). Locate the generator (if applicable) downwind of the well; connect the power converter to the generator and to the pump.

1.4 WELL PURGING AND SAMPLING PROCEDURE

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.
- Connect the flow-through cell or clean container containing the instrumentation header to the pump discharge and begin purging the well at 0.2-0.5 L/min, unless a different purge rate has been previously established for that well. Fill the flow cell completely. Care should be taken not to cause entrapment of air in the system. Record the purge start time and purge rate.
- Establish that the water level has not dropped significantly such that the pump is dry (bubbles in discharge) or water is heard cascading down the inside of the well. Ideally, the pump rate should cause little or no water level drawdown in the well (>0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If water levels continue to drop with the pump on the lowest flow rate, the pump will be shut off and the well will be allowed to recharge to prevent the well from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.
- During purging of the well, monitor the water quality indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every 3-5 minutes (or as appropriate). Record purge rate, volume purged, depth to water, water quality indicator parameters values, and clock time at 3- to 5-minute intervals in field logbook and sampling record. Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within approximately 10 percent. Turbidity readings consistently below 10 nephelometric turbidity units (NTU) are considered to represent stabilization of discharge water for this parameter. If the parameters have stabilized, but the turbidity is not in the range of the 10 NTU goal, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes.
- Purge water at a well will be containerized if a well has exceeded the MEG or MCL in previous sampling events. Any purge water that is collected will be treated at the groundwater treatment plant.

- Prior to sampling, disconnect the discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing. Record pertinent observations in field logbook and sampling records.
- Begin filling sample containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible. Collect the samples in the order below, as applicable:
 - VOCs
 - Inorganics.
- VOC samples requiring pH adjustment will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Details on sample preservation are discussed in Section 1.5.
- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.
- After collection of the samples, restore the dedicated pumping assembly to the well by hanging the tube, electric line, and support cable inside the well by the specially-designed PVC well cap assembly. Lock well.
- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP048-1) after each well is sampled, including sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

1.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Pre-preserved bottles will be used if possible. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs**—Aqueous VOC samples must be collected as specified below. Each VOC sample is taken in duplicate:
 - Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.
 - Fill a sample bottle, preserve with HCl, and check the pH. Adjust the volume of HCl to assure pH<2.

- Add the amount of HCl determined in the above step, and fill the sample vial slowly from the tubing, minimizing air entrainment, until the vial slightly overflows.
- Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down and screw cap on.
- Invert the bottle, tap lightly, and check for air bubbles.
- If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.
- Place samples on ice until shipment.
- **Inorganics**—Fill the sample bottle, preserve the sample to pH<2 with nitric acid (HNO₃), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples if necessary. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

1.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each sample delivery group (SDG) (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG.
- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent.
- Equipment Rinsate Blank—Required once prior to installation of dedicated pump systems.
- Source Water Blank—Required at a frequency of once per source per sampling event when equipment (rinsate) blank is required.
- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.

1.7 DECONTAMINATION

Non-dedicated sampling equipment and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternative procedures must be approved by the Project Manager prior to sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

2. GROUNDWATER SAMPLING BY LOW-FLOW PURGE AND SAMPLING METHOD USING PERISTALTIC PUMPS

2.1 SCOPE OF APPLICATION

The purpose of this SOP is to establish the protocol for collecting groundwater samples using peristaltic pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity, and is intended to be used in conjunction with the analyses for the most common types of groundwater contaminants (VOCs and inorganic compounds).

2.2 EQUIPMENT/MATERIALS

- Work Plan.
- Well construction data, location map, field data from last sampling event.
- Field logbook and Field Record of Well Gauging, Purging, and Sampling forms (Figure SOP048-1).
- Water level measuring device, 0.01 ft accuracy (electronic preferred) for monitoring water level drawdown during pumping operations.
- Peristaltic pump.

- In-well tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic analysis. For samples collected for inorganics analysis, Teflon or Teflon-lined polyethylene, PVC, Tygon, or polyethylene tubing may be used.
- Pump head tubing: Silicon tubing must be used to in the pump head assembly.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (battery, etc.).
- Water quality indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Optional indicators – Eh and dissolved oxygen.
- Flow-through cell (preferred) or clean container for water quality probe.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.
- Drum for purge water containment.

2.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.
- Check well for damage or evidence of tampering, record pertinent observations in field logbook and sampling form.
- Unlock well and remove well cap (if applicable).
- Measure VOCs with an ionization detector (photo or flame) instrument at the rim of the well and in the breathing zone and record the readings in the field logbook and the sampling form.

- Measure and record the height of protective casing above the concrete pad, or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.
- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. If a reference point is made, it will be noted in the field logbook. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will not be measured following the completion of sampling because of the potential to stir up sediment at the bottom of the well.
- Position the intake of the sampling hose at the mid-point of the screened interval.
- Prepare the pump by checking electrical connections and discharge tubing. Locate the battery downwind of the well; connect the peristaltic pump to the battery.

2.4 WELL PURGING AND SAMPLING PROCEDURES

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.
- Measure the water level with the pump in well before starting the pump. Begin purging the well at 0.3-0.5 L/min, unless a different purge rate has been previously established for that well.
- If well diameter permits, establish that the water level has not dropped significantly such that the pump is dry (air in discharge) or tubing suction is broken. Ideally, the pump rate should cause little or no water level drawdown in the well (>0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Care should be taken not to cause pump suction to be broken, or entrainment of air in the pump system. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.3 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If water levels continue to drop with the pump on the lowest flow rate, the pump will be shut off and the well will be allowed to recharge to prevent the well from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.

- During purging of the well, monitor the field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every 3-5 minutes (or as appropriate). Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within approximately 10 percent. Turbidity readings consistently below 10 NTU are considered to represent stabilization of discharge water for this parameter. If the parameters have stabilized, but the turbidity is not in the range of the 10 NTU goal, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes.
- Purge water at a well will be containerized if a well has exceeded the MEG or MCL in previous sampling events. Any purge water that is collected will be treated at the groundwater treatment plant.
- Prior to sampling, disconnect the sample discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing.
- Collect groundwater samples directly from the silicon tubing into preserved (when appropriate) sample containers. Begin filling sample containers from the pump discharge, allowing the water to fill the containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible. Collect the samples in the order below, as applicable:
 - VOCs
 - Inorganics.
- VOC samples requiring pH adjustment will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Detail on sample preservation are discussed in Section 2.5.
- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.
- After collection of the samples, restore the dedicated tubing assembly to the well by hanging the tube inside the well by the specially-designed PVC well cap assembly. Lock well.
- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP048-1) after each well is sampled, including: sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

- The silicon tubing used in the peristaltic pump will be changed after use at each well.

2.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Pre-preserved bottles will be used if possible. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs**—Aqueous VOC samples must be collected as specified below. Each VOC sample is taken in duplicate:
 - Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.
 - Fill a sample bottle, preserve with HCL, and check the pH. Adjust the volume of HCL to assure $\text{pH} < 2$.
 - Add the amount of HCL determined in the above step, and fill the sample vial slowly from the tubing, minimizing air entrainment, until the vial slightly overflows.
 - Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down, and screw cap on.
 - Invert the bottle, tap lightly, and check for air bubbles.
 - If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.
 - Place samples on ice until shipment.
- **Inorganics**—Fill the sample bottle, preserve the sample to $\text{pH} < 2$ with nitric acid (HNO_3), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples if necessary. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

2.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each SDG (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG
- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent
- Equipment (Rinsate) Blank—Required once prior to installation of dedicated sample tubing
- Source Water Blank—Required at a frequency of one per source per sampling event
- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.
- Temperature Blank—Required at a frequency of once per sample shipment container.

2.7 DECONTAMINATION

Non-dedicated sampling and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternate procedures must be approved by the Project Manager prior to the sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

3. SURFACE WATER AND LEACHATE SEEP SAMPLING PROCEDURE

3.1 SCOPE OF APPLICATION

The purpose of this SOP is to establish the protocol for collecting surface water and leachate seep samples. The procedure is designed to permit the collection of representative surface water and leachate seep samples, and has been adapted from the procedure outlined in the Work Plan. This SOP is suitable for collecting surface water and seep samples requiring analyses for the most common types of surface water contaminants (VOCs and inorganic compounds).

3.2 EQUIPMENT/MATERIALS

- Work Plan.
- Location map, field data from last sampling event.
- Field logbook and Field Record of Surface Water and Sediment Sampling forms (Figure SOP048-2).
- Water quality indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Optional indicators – Eh and dissolved oxygen.
- Decontamination supplies (for monitoring instrumentation).
- Dedicated, pre-cleaned 1-L wide-mouth or volatile organic analyte sample container (for sample collection).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.

3.3 PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing surface water or leachate seep sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, sample station identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.

- Visually inspect sample station for evidence of changes in physical condition; record pertinent observations in field logbook and sampling form.
- Measure VOCs with a flame ionization detector instrument in the breathing zone and record the reading in the field logbook and sampling form.

3.4 SAMPLING PROCEDURE

The technique for surface water and leachate seep sampling must be selected after addressing such items as:

- Depth of waterbody
- Depth of sample
- Stratification
- Seasonal variations
- Analytical parameters of interest.

The following general procedure should be used to obtain representative surface water and leachate seep samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to sampling: date and time, sample method, and sample depth.
- Collect the sample from the surface water, within several tenths of a foot of the streambed, by immersing a new, dedicated 1-L glass or volatile organic analyte sample container into the waterbody. If a stream is being sampled, collect the sample upstream of the sampler with the opening of the sampling device oriented upstream but avoiding floating debris.
- Directly fill the appropriate sample containers from the 1-L or volatile organic analyte sampling device.
- Collect the samples in the order below, as applicable:
 - VOCs
 - Inorganics.
- Water sample containers are generally filled directly from the source or sampler without special considerations. The exception is the collection of aqueous VOC samples requiring pH adjustment. VOC samples will have their pH checked to assure that the proper pH has been obtained. This will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling. Details on sample preservation methods are discussed in Section 3.6.

- Label each sample as collected. Those samples (VOCs, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Inorganic samples, after preservation, do not need to be cooled.
- Measure water quality indicator parameters, if possible, by direct immersion of instrument probes into the waterbody immediately following sample collection. If direct measurement is not possible, measure these parameters from water remaining in the sampling device or another sample bottle. Record this information in the field logbook and sample data record.
- Complete remaining portions of the Field Record of Surface Water and Sediment Sampling form (Figure SOP048-2) after each station is sampled, including: time of sample collection, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

3.5 SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Minimum sample preservation requirements for each parameter group are summarized below:

- **VOCs**—Aqueous VOC samples must be collected as specified below. Each sample is taken in duplicate:
 - Uncap the sample bottle, taking care not to touch the Teflon-faced septum. If the septum is contaminated in any way, it should be replaced.
 - Fill a sample bottle, preserve with HC1, and check the pH. Adjust the volume of HC1 to assure $\text{pH} < 2$.
 - Add the amount of HC1 determined in the above step, and fill the sample vial slowly from the 1-L container, minimizing air entrainment, until the vial slightly overflows.
 - Place the Teflon-faced silicon rubber septum on the convex meniscus, Teflon side (shiny side) down and screw cap on.
 - Invert the bottle, tap lightly, and check for air bubbles.
 - If air bubbles are present, open the bottle, add sample to eliminate air bubbles, and reseal. Repeat this procedure until the bottle is filled and no air bubbles are detected.
 - Place samples on ice until shipment.

- **Inorganics**—Fill the sample bottle, preserve the sample to pH<2 with nitric acid (HNO₃), seal container, and place sample on ice for shipment.

Disposable pipettes should be used to introduce chemicals into the samples. Chemicals used for preserving should be poured into a 150-ml beaker. They should not be drawn directly from the preservative bottles because the bottle may become contaminated. Measurements for pH and temperature should not be taken from the sample containers. When preserving samples to a required pH, pH paper should be used to check the resultant pH. The sample should be poured across the pH paper. Never place pH paper directly into sample.

NOTE: Shipping regulations limit the amount of preservative which can be added. For a 1-L sample, this is generally 1.5 ml of acid preservative.

3.6 FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the surface water and leachate seep samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each SDG (an SDG may not exceed 20 samples) at the frequency noted:

- Field Duplicate—Required at a frequency of 10 percent per SDG.
- Matrix Spike/Matrix Spike Duplicate—Required at a frequency of 5 percent.
- Equipment (Rinsate) Blank—Required at a frequency of once per day per media sampled.
- Source Water Blank—Required at a frequency of once per source per sampling event when equipment (rinsate) blank is required.
- Trip Blank—Required for VOC samples at a frequency of one per sample shipment.

3.7 DECONTAMINATION

Field monitoring equipment will be decontaminated prior to use and following sampling of each station by the procedure listed below. Laboratory pre-cleaned, dedicated 1-L glass sample collection containers are used once and discarded and, therefore, do not undergo any decontamination. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

4. REFERENCES

U.S. Environmental Protection Agency. 1996. Groundwater Issue-Low Flow Sampling (Minimal Drawdown) Groundwater Sampling Procedures. April.

**FIELD RECORD OF WELL GAUGING, PURGING, AND SAMPLING**

Site Name:	_____	Project Number:	_____
Well ID:	_____	Well Lock Status:	_____
Well Condition:	_____	Weather:	_____

Gauge Date:	_____	Gauge Time:	_____
Sounding Method:	_____	Measurement Ref:	_____
Stick Up/Down (ft):	_____	Well Diameter (in.):	_____

Purge Date:	_____	Purge Time:	_____
Purge Method:	_____	Field Personnel:	_____
Ambient Air VOCs (ppm):	_____	Well Mouth VOCs (ppm):	_____

WELL VOLUME			
A. Well Depth (ft):	_____	D. Well Volume/ft (L):	_____
B. Depth to Water (ft):	_____	E. Well Volume (L) (C*D):	_____
C. Liquid Depth (ft) (A-B)	_____	F. Three Well Volumes (L)	_____
G. Measurable LNAPL? Yes _____ /ft No _____			

Parameter	Beginning	1	2	3	4	5
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Total Quantity of Water Removed (L):		_____	
Samplers:	_____	Sampling Time (Start/End):	_____
Sampling Date:	_____	Decontamination Fluids Used:	_____
Sample Type:	_____	Sample Preservatives:	_____
Sample Bottle IDs:	_____		
Sample Parameters:	_____		

Figure SOP048-1.

**FIELD RECORD OF WELL GAUGING, PURGING, AND SAMPLING**

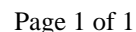
Site Name: _____	Project Number: _____	Date: _____
Well ID: _____	Field Personnel: _____	

Parameter	6	7	8	9	10	11
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Parameter	12	13	14	15	16	17
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Comments and Observations:

Figure SOP048-1.



Site Name:			Project Number:
Sample Location ID:			Date:
Time:	Start:	End:	Sample Team Members:

[illegible]

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Figure SOP048-2.



Standard Operating Procedure No. 051 for Low Flow Purge and Sampling with Dedicated Pumps

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1. SCOPE OF APPLICATION

The purpose of this Standard Operating Procedure is to establish the protocol for collecting groundwater samples using dedicated pump systems. The procedure is designed to permit the collection of groundwater samples with minimum turbidity, and is intended to be used in conjunction with the analyses for the most common types of groundwater contaminants (volatile organic compounds and semivolatile organic compounds, pesticides, polychlorinated biphenyls, metals, and inorganic compounds). This Standard Operating Procedure was prepared based on draft guidance prepared by U.S. Environmental Protection Agency Region 1 and conforms with the procedures described in the Long-Term Monitoring Plan.

2. EQUIPMENT/MATERIALS

- Long-Term Monitoring Plan.
- Well construction data, location map, and field data from last sampling event.
- Field logbook, Field Record of Well Gauging Form (Figure SOP051-1), and Field Record of Well Gauging, Purging, and Sampling Form (Figure SOP051-2).
- Electronic water level measuring device, 0.01 ft accuracy for monitoring water level during pumping operations.
- Pumps: adjustable rate, submersible pumps constructed of stainless steel and Teflon.
- Tubing: Teflon or Teflon-lined polyethylene must be used to collect samples for organic and inorganic analyses.
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Power source (generator, etc.).
- Water quality indicator parameter monitoring instruments—pH, turbidity, specific conductances, and temperature. Optional indicators—Eh and dissolved oxygen. Water quality indicator parameters will be measured in the field in accordance with EPA-600/4-79-020 (1983) using the following methods: temperature (Method 170.1), pH (Method 150.1), turbidity (Method 180.1), specific conductance (Method 120.1), and dissolved oxygen (Method 360.1).

- Flow-through cell for water quality parameters.
- Decontamination supplies (for monitoring instrumentation).
- Sample bottles and sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Cooler with bagged ice for sample bottles.

3. PRELIMINARY SITE ACTIVITIES

The following site activities are required prior to performing well purging and groundwater sampling. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate: site name, project number, field personnel, well identification, weather conditions, date and time, equipment used, and quality assurance/quality control data for field instrumentation.
- Check well for damage or evidence of tampering, record pertinent observations in field logbook and sampling form.
- Lay out sheet of polyethylene for monitoring and sampling equipment.
- Unlock well and remove well cap (if applicable).
- Measure volatile organic compounds with a photoionization detector instrument at the rim of the well and in the breathing zone, and record the readings in the field logbook and the sampling form.
- Measure and record the height of protective casing above the concrete pad or ground surface, as appropriate. This reading is compared to that recorded during well installation as an indication of possible well damage or settling that may have occurred.
- Measure and record the depth to water (to 0.01 ft) in the well to be sampled before purging begins. If the well casing does not have a reference point (usually a v-cut or indelible mark in the well casing), make one. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well. The depth to well bottom will be measured following completion of the sampling because of the potential to stir up sediment at the bottom of the well.

- Prepare the pump by checking electrical connections, discharge tubing, and motor (Grundfos Redi-Flo2). Locate the generator (if applicable) downwind of the well; connect the power converter to the generator and the pump.

4. SAMPLING PROCEDURE

The following general procedure should be followed to obtain representative groundwater samples. Field logbooks and sampling forms should be filled out as the procedure is being performed, as noted:

- Enter the following information in the field logbook and sampling form, as appropriate, prior to purging: purge date and time, purge method, and total well depth.
- Connect the flow-through cell containing the instrumentation header to the pump discharge and begin purging the well at 0.2-0.5 L/min, unless a different purge rate has been previously established for that well. Fill the flow-through cell completely. Care should be taken not to cause entrapment of air in the system. Record the purge start time and purge rate.
- Establish that the water level has not dropped significantly such that the pump is dry (bubbles in discharge) or water is heard cascading down the inside of the well. Ideally, the pump rate should cause little or no water level drawdown in the well (<0.5 ft and the water level should stabilize). The water level should be monitored every 3-5 minutes (or as appropriate) during pumping. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 L/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If the water level continues to drop with the pump on the lowest flow rate, the pump will be shut off and the well allowed to recharge to prevent it from going dry. **The well will not be purged to dryness prior to sampling to prevent erroneous field parameters and groundwater samples.** Sampling will commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.
- During purging of the well, monitor the water quality indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every 3-5 minutes (or as appropriate). Record purge rate, volume purged, depth to water, water quality indicator parameters values, and clock time at 3- to 5-minute intervals in field logbook and sampling record. Purging of the standing well water is considered complete when three consecutive readings of the water quality indicator parameters agree within approximately 10 percent. Turbidity readings consistently below 10 nephelometric turbidity units (NTUs) are considered to represent stabilization of discharge water for this

parameter. If the parameters have stabilized, but the turbidity is not in the range of the 10 NTU goal, the pump flow rate should be decreased and measurement of the parameters should continue every 3-5 minutes.

- Prior to sampling, disconnect the discharge tubing from the flow-through cell. If the water discharged by the pump is silty, wait for the water to clear before sampling. Ensure that bubbles are not observed in the discharge tubing. Record pertinent observations in field logbook and sampling records.
- The purging rate will be controlled so that the well is not purged dry before sampling. If necessary, purging will be temporarily halted to permit recharge rather than allowing the well to be purged dry.
- Begin filling sample containers from the pump discharge, allowing the water to fill the containers by allowing the pump discharge to flow gently down the inside of the container with as little agitation or aeration as possible.
- Label each sample as collected. Those samples requiring cooling will be placed into an ice cooler for delivery to the laboratory.
- After collection of the samples, restore the dedicated pumping assembly to the well by hanging the tube, electric line, and support cable inside the well by the specially-designed PVC well cap assembly. Lock well.
- Complete remaining portions of Field Record of Well Gauging, Purging, and Sampling form (Figure SOP051-2) after each well is sampled, including sample date and time, total quantity of water removed, well sampling sequence, types of sample bottles used, sample identification numbers, preservatives used, parameters requested for analysis, and field observations of sampling event.

5. SAMPLE PRESERVATION

The following preservation procedures are examples of typical preservation protocols specific to the indicated analyses. Minimum sample preservation requirements for each parameter group are summarized below and in Table 3-1 of the Quality Assurance Project Plan:

- **Pesticides and Herbicides**—Fill the sample bottle, seal with a Teflon-lined cap, and place on ice for shipment.

6. FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the groundwater samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each sample delivery group (a sample delivery group may not exceed 20 samples) at the frequency noted:

- **Field Duplicate**—Required at a frequency of 10 percent per sample delivery group
- **Matrix Spike/Matrix Spike Duplicate**—Required at a frequency of 5 percent
- **Equipment Rinsate Blank**—Required once prior to installation of dedicated pump systems
- **Source Water Blank**—Required at a frequency of once per sampling event when equipment rinsate blank is required.
- **Trip Blank**—Required for volatile organic compound samples at a frequency of one per sample shipment.

NOTE: The dedicated pumps remain in the wells between sampling events.

7. DECONTAMINATION

Non-dedicated sampling equipment and field monitoring equipment will be decontaminated prior to use and following sampling of each well. This equipment will be decontaminated by the procedure listed below. Alternative procedures must be approved by the Project Manager prior to sampling event. Decontamination fluids will be collected in a 5-gal bucket and treated at the groundwater treatment plant.

The following decontamination procedure will be used:

- Flush the equipment with potable water
- Flush with non-phosphate detergent solution
- Flush with tap water to remove all of the detergent solution
- Flush with distilled/deionized water
- Flush with isopropyl alcohol
- Flush with distilled/deionized water.

It is recommended that the detergent and isopropyl alcohol used in the above sequence be used sparingly.

FIELD RECORD OF WELL GAUGING

[illegible]

FIELD RECORD OF WELL GAUGING, PURGING, AND SAMPLING

Site Name:	_____	Project Number:	_____
Well ID:	_____	Well Lock Status:	_____
Well Condition:	_____	Weather:	_____

Gauge Date:	_____	Gauge Time:	_____
Sounding Method:	_____	Measurement Ref:	_____
Stick Up/Down (ft):	_____	Well Diameter (in.):	_____

Purge Date:	_____	Purge Time:	_____
Purge Method:	_____	Field Personnel:	_____
Ambient Air VOCs (ppm):	_____	Well Mouth VOCs (ppm):	_____

WELL VOLUME	
A. Well Depth (ft):	D. Well Volume/ft (L):
B. Depth to Water (ft):	E. Well Volume (L) (C*D):
C. Liquid Depth (ft) (A-B)	F. Three Well Volumes (L)
G. Measurable LNAPL? Yes _____ /ft No _____	(E*3):

Parameter	Beginning	1	2	3	4	5
Time (min.)						
Depth to Water (ft)						
Purge Rate (L/min)						
Volume Purged (L)						
pH						
Temperature (°C)						
Conductivity (µmhos/cm)						
Dissolved Oxygen (mg/L)						
Turbidity (NTU)						
eH (mV)						

Total Quantity of Water Removed (L):		_____	
Samplers:	_____	Sampling Time (Start/End):	_____
Sampling Date:	_____	Decontamination Fluids Used:	_____
Sample Type:	_____	Sample Preservatives:	_____
Sample Bottle IDs:	_____		
Sample Parameters:	_____		



Standard Operating Procedure No. 053 for Concrete Coring

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Revision 0
April 2008

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1. SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) details all procedures for the concrete coring machine, an electrically operated coring drill. The procedures described within the SOP include, from beginning to end, setup, coring, and teardown of equipment. This SOP also includes equipment lists of the coring machine and accessories needed when coring.

Use of the concrete coring machine is a quick and clean method for penetrating concrete with up to 12 in. of thickness. Concrete coring is a good method when collecting samples from under a concrete surface is required with minimal physical damage to property.

When contaminated materials are anticipated, other precautions of a safety and health nature must be addressed. It is very important that the water be used throughout the coring process as described below in order to limit the production of airborne dust during the process.

1.1 PURPOSE

The purpose of this SOP is to provide a detailed outline of procedures for setup through teardown of concrete coring. This SOP includes an equipment and parts list as well as step by step coring procedures.

1.2 SCOPE

The procedures outlined in this SOP are applicable to all EA personnel using a concrete coring machine as well as any subcontractors EA is responsible for.

2. DEFINITIONS

The concrete coring machine has many specific and specialized parts. For this reason, familiarity with the coring drill, coring stand, and accessories is necessary. These terms are discussed below.

2.1 CORING MACHINE TERMS

The following terms are principally used to discuss the basic operation of the concrete coring machine and its major components.

Vacuum Base—The base of the coring machine stand. This is what is anchored to the ground through the middle slot. This base also has four 0.5-in. bolts, one in each corner for leveling.

Column with Gear Rack—Mounted vertically to the vacuum base with two 0.5-in. bolts. It also has a gear rack on the back side to enable the motor to move up and down smoothly for a good core.

Carriage—The piece that the motor is mounted on. This piece slides over the top of the column with gear rack and has a pinion shaft to enable the carriage with mounted motor to move smoothly on the column.

Ceiling Jack—A threaded piece that screws into the top of the column to enable the user to secure the coring machine to the ceiling or overhead support.

Square Head Set Screw—There are four of these 5/8-in. × 4-in. bolts, one located at each corner of the vacuum base. These bolts are used to level the coring machine (keep oiled).

Drill—The motor/drill, which is the main piece of equipment. It is usually 15-20 amps and has a drill shaft of 5/8 in. or 7/8 in.

Drill Shaft—The threaded piece that comes out of the motor which is the attachment point for the drill bit.

Extension—A metal rod used for core drilling deeper holes. The extension is threaded between the core bit and motor shaft

2.2 DRILL BIT TERMS

Barrel—Common term used for the tube or body of a core bit. The barrels are normally made of steel and are also called a core.

Continuous Rim—Type of bit that has no gullets or spaces between segments. This type of bit is good for smooth cutting.

Gullet—The slots in a core bit that provide faster cooling by allowing water or air to flow between the segments. These also allow the blade to flex under cutting pressure.

Fine Diamond—Smaller sized diamond crystals used for fast cutting.

Hub—The cap of a core bit that is usually welded or screwed into a core barrel. This has threads which screw onto a drill motor.

Stress Cracks—Small cracks that form in the blade core due to too much pressure put on the blade. These also occur because of overheating and if the bond is too hard for the material being cut.

2.3 CORE DRILLING TERMS

Aggregate—Rocks and minerals that are put into cement to make concrete. The type of aggregate determines how hard or soft concrete and asphalt are.

Anchor—Secures the coring machine to the work surface to prevent movement during drilling. Movement during drilling will cause chatter of bit against the work surface, fracturing diamonds and damage to core bit.

Inverted Drilling—Drilling upside down.

Slurry—Mud-like material that is the result of concrete cutting with water as a coolant.

3. MATERIALS

The following materials may be required:

- Coring machine
- Coring bit
- Generator that provides 20 amps
- At 50 ft, you need 14-gauge extension cords
- At 75-100 ft, you need 12-gauge extension cords
- GFI plug
- Hammer drill with 5/8-in. bit
- 0.5-in. drop in concrete anchors
- 0.5-in. threaded rod 1-ft long with 2 hex nuts
- Wrench to tighten hex nuts
- Water hose
- Water supply
- Shop vacuum
- Bullet level.

4. PROCEDURES

4.1 SET UP CORING MACHINE

- Once at location, set coring machine with bit directly over location of core.
- Get hammer drill with 5/8-in. bit and drill a hole through the slot in the middle of the vacuum base, deep enough to set your 0.5-in. drop in concrete anchor.
- Set concrete anchor.
- Take 0.5-in. threaded rod with hex nuts, and screw into drop in anchor.
- Get your bullet level and level your coring machine, using the 5/8-in. square head set screws located at each corner of the vacuum base. **Getting the machine level is the most important step.**

- Once your machine is level, tighten down the hex nuts on the threaded rod in the center of the vacuum base. The coring machine is now secured to the concrete.
- Connect the machine to a power supply using an extension cord of the appropriate length and a Ground Fault Circuit Interrupter.
- Connect water hose to coring machine.

4.2 CORING

Before coring, double check all connections and be sure the coring machine is still level.

- When first starting the machine, turn on the water and set the flow rate at a sufficient volume to cool the bit while coring.
- Using the lever located on the carriage, slowly lower the drill until the bit contacts the concrete. It is important that this is lowered slowly because a rotating bit is not stable and can bounce or even break the bit if advanced too quickly.
- Once the bit is advanced approximately halfway into the concrete, it will be safe to start applying more pressure to the lever to speed up the coring process. Some concrete has heavier aggregate and steel reinforcement that could stress the electric motor; therefore, frequently check the motor for overheating.
- It will be apparent when the coring machine has reached the bottom of the concrete; the underlying soil will feel soft. **Immediately turn off the water.**
- Using the lever on the carriage, raise the bit above the top of the concrete then turn off the machine.
- Remove the concrete core.

The coring is complete.

5. REFERENCES

The following references were used to prepare this SOP.

Dewalt website. www.dewalt.com.

Diamant Boart Inc. 1999. Core Drilling Machine Manual.

Glossary of terms. http://www.diamondproducts.com/glossary_of_terms.htm.

Standard Operating Procedure for the Snap Sampler® Passive Groundwater Sampling Method (March 2009)

2009 UPDATE

The 2009 update includes graphics and descriptions of three different Snap Sampler® trigger options: manual, electric and pneumatic; and three bottle size options: 40ml glass VOA, 125ml plastic, and 350ml plastic. This Standard Operating Procedure (SOP) should be used to familiarize the user with the application and protocol for use the Snap Sampler® passive groundwater monitoring system. The Appendices contain step-by-step field instructions. The Appendices, rather than the SOP itself, should be the primary field tool for Snap Sampler® operation. The SOP is designed for overall understanding and rationale for passive groundwater sampling with the Snap Sampler®, and for regulatory submittal with Sampling and Analysis Plans. Should the user require information beyond that included in this SOP, additional information can be found on the Snap Sampler® website SnapSampler.com or by contacting your Snap Sampler representative.



FORWARD

This SOP was adapted from SOPs in USEPA's groundwater guidance for RCRA and Superfund project managers (U.S. Environmental Protection Agency, 2002). Portions of the applicable text are repeated here. With this forward, the authors and USEPA are acknowledged in sincerest appreciation. Edited and supplemental text is included to detail application information and procedures for use and deployment of the Snap Sampler® passive groundwater sampling device and method.

INTRODUCTION

The goal of groundwater sampling is to collect samples that are representative of *in situ* groundwater conditions and to minimize changes in groundwater chemistry during sample collection and handling. Experience has shown that groundwater sample collection and handling procedures can be a source of variability in water quality concentrations due to differences in sampling personnel, sampling procedures, and equipment (U.S. Environmental Protection Agency, 1995).

Traditionally, the collection of representative water samples from wells is neither straightforward nor easily accomplished. Groundwater sample collection through pumping or bailing can be a source of variability through differences in sampling personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at groundwater monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample collection procedures.

The purpose of this SOP is to provide a description of the Snap Sampler® passive groundwater sampling method. The method and specialized equipment is designed to minimize the impact the sampling process on groundwater chemistry. This is accomplished through deployment and

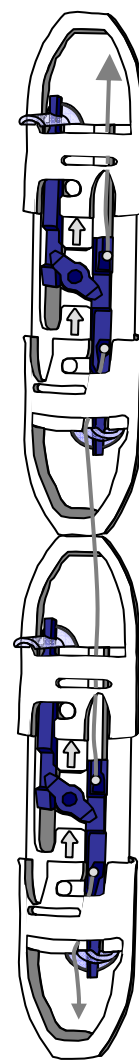


Figure 1

passive re-equilibration of the monitoring well to ambient groundwater flow and/or diffusive contaminant flux within the well/aquifer system. The Snap Sampler® method eliminates well purging prior to sample collection.

As a passive groundwater sampling device, the Snap Sampler® is a proven, cost-effective alternative to well purge and low-flow sampling. Historical and recent research shows that most if not virtually all well screen zones exhibit ambient flow-through under natural groundwater gradients (Gillham, 1982; Pankow, et al 1985; Robin and Gillham, 1987; Powell and Puls, 1993; Puls and Barcelona, 1996; Vroblesky, et al, 2001a; ASTM, 2002; ITRC, 2004, 2007). The screen sections of these wells are “naturally purged” without pumping. Ongoing research suggests that natural ambient flow can induce mixing within wells (Britt, 2005, 2007, 2008; Martin-Hayden and Britt, 2006; Vroblesky, et al 2006; Britt and Calabria, 2008). This mixing effect results in a flow-weighted averaging effect in the well *without purging*. Though not all wells are thoroughly mixed, many wells show relatively narrow ranges of vertical concentrations when vertically profiled (Vroblesky et al, 2001b; Parsons, 2003; Britt and Calabria, 2008). These studies and others indicate flow-weighted contaminant concentration averaging within wells may be common. The Snap Sampler® takes advantage of “naturally purged” wells by capturing a whole water sample after a period of sampler deployment in the well.

Wells in poor yielding formations with slow recharge during pumping have always been problematic for pumping methods. Wells with short water column are also problematic for some of the same reasons. Passive sampling of poorly yielding wells has been suggested as a better method than purging to dryness in VOC impacted wells (McAlary and Barker, 1987; Puls and Powell, 1993; Puls and Barcelona, 1996). The Snap Sampler® can be deployed in low yield and short water column wells to take advantage of the non-purge technology.

The Snap Sampler® (Figure 1) passive groundwater sampling method limits sample collection variables by sealing the sample

while it is still in the well, at the same position in the well during each sampling event. Where appropriate, the sample is not poured into sample bottles at the ground surface. Using this approach, sampling personnel are essentially prevented from introducing error, variability, or bias during the sample collection process. Sample collection is virtually the same for any collector because the sample is captured downhole the same way every event, without impact from user technique, and in many cases, not exposed to the ambient air from the well to the laboratory. Recent research shows that variable reduction may improve long-term data trend analysis (Britt, 2008).

SCOPE AND APPLICATION

This SOP should be used primarily at monitoring wells that have a screen or an open interval with a length of ten feet or less and can accept a downhole device of 1.7 inches (4.3cm) in diameter. Longer screen interval sampling may be conducted, but vertical stratification testing is more likely to be required to test for vertical concentration gradients. Vertical stratification monitoring may be warranted if previous information about aquifer and/or well contaminant stratification is not available. Vertical profiling may be recommended depending on site-specific data quality objectives (DQO's) and other site requirements (Vroblesky, 2001a; ITRC, 2004, 2007).

The groundwater samples that are collected using this procedure are useable for the analyses of groundwater contaminants that may be found at Superfund and RCRA contamination sites, as well as sites with a variety of contamination types. The analytes may be volatile organic compounds, semi-volatile organic compounds, pesticides, PCBs, metals, and other inorganic compounds, including perchlorate and other emerging contaminants such as explosive compounds, 1,4-dioxane, 1,2,3-TCP, NDMA and others.

For contaminant plume monitoring, the sampler should be placed within the screened interval of the well. For consistency and comparability of results over time, the sampler should be placed in same location or

depth for each subsequent sampling event. This argues for the use of dedicated sampling devices with dedicated trigger lines whenever possible. If this is not possible, then the placement of the Snap Sampler® should be positioned using pre-measured trigger line placed at the same depth during each sampling event. The Snap Sampler® should not be placed resting on the bottom well to avoid disturbing any sediment at the bottom of the well during deployment or when the sampler is triggered.

The Snap Sampler® relies on natural flow-through and/or diffusion of contaminants from the aquifer to the well (Powell and Puls, 1993; ASTM, 2002; ITRC, 2004, 2007). Well purging is not conducted before sampling, therefore, *measurement of water-quality-indicator parameters is not a prerequisite to sample collection*. If parameters are required for certain monitoring programs independent of sampling method (e.g. for monitored natural attenuation assessment), parameters can be collected by utilizing one of the deployed Snap Sampler® bottles or post-sampling by another method (e.g. a downhole probe).

Samples collected for metals, semi-volatile organic compounds, pesticides, and other analytes may be impacted by sample turbidity. They also may be subject to transport by colloidal flow in the natural groundwater regime (Kearl, et al, 1992, Puls and Powell, 1992). Deployment and re-equilibrium of the Snap Sampler® allows natural colloidal flow to be monitored within the well. This is a distinct advantage over sampling methods such as the polyethylene diffusion bag (PDB), where colloidal particles are excluded from the sample; and an advantage over purge methods where colloids may be artificially mobilized. Field filtering is not required for samples collected with the Snap Sampler® but can be conducted if required by the site Sampling and Analysis Plan.

Proper well construction, development, and maintenance are essential for any groundwater sampling procedure. Prior to conducting the field work, information on the construction of the well and well development should be obtained and that information

factored into the site specific sampling procedure. This SOP is not to be used where non-aqueous phase liquids (NAPL) (immiscible fluids) are present in the monitoring well.

MATERIALS AND EQUIPMENT

- Approved Field Sampling and Quality Assurance Project Plan.
- Site Health and Safety Plan with specifications for personal protective equipment and air monitoring equipment.
- Personal protective equipment in good working order as specified in the site Health and Safety Plan.
- Air monitoring equipment in good working order as specified in the Site Health and Safety Plan.
- Site access/permission documentation for site entry.
- Well keys and map of well locations.
- Tool box - All needed tools for all site equipment used.
- Snap Samplers® - Dedicated samplers are recommended in most applications.
- Snap Sampler® Trigger lines, – Dedicated trigger lines are recommended in most applications. Trigger lines may be manual, with a mechanical wire connection from surface to sampler; electric, with a wireline from surface to sampler; or pneumatic, with an airline from surface to sampler.
- Snap Sampler® Well Docking Station – Lockable well caps for Snap Sampler® - deployed wells—includes a support ring to hang Snap Sampler equipment.
- Sample bottles, sample preservation supplies, sample tags or labels, and chain-of-custody forms.
- Well construction, field, and water quality data from the previous sampling event.

- Field notebook, groundwater sampling logs, and calculator.
- Polyethylene sheeting placed on ground around the well head.
- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for determination of liquid products (NAPL) presence, if needed.
- Steel tape and weight - Used for measuring total depth of well.
- Multi-parameter meter, if required. The water-quality-indicator parameters that may be monitored under common monitoring programs include pH, ORP/Eh, (ORP) dissolved oxygen (DO), turbidity, specific conductance, and temperature. Turbidity readings, if required, must be collected from a sacrificed Snap Sampler® bottle because retrieving the sampler may agitate the well, increasing turbidity values not present in the actual samples. Calibration fluids for all instruments should be NIST-traceable and there should be enough for daily calibration throughout the sampling event.
- Decontamination supplies - Including a reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap will also be needed.
- A suitable container for excess sample and decontamination water, as needed or required.

Construction materials of the sampling equipment (samplers, tubing, and other equipment that comes in contact with the sample) should be limited to stainless steel, Teflon®, glass, and other inert material. This will reduce the chance that sampling materials alter the groundwater where concentrations of the site contaminants are expected to be near the detection limits. The tendency of organics to sorb into and desorb out of plastic materials makes dedicated equipment preferable where possible.

It should be noted that plastic materials used in the Snap Sampler® are not usually problematic for sorption. Using methods described in this SOP, the sampler is deployed for one to two weeks (or more). This deployment period allows materials prone to sorption to achieve equilibrium with groundwater before the sample is collected.

DEPLOYMENT/SAMPLING PROCEDURES

The following describes the deployment and sampling procedures for the Snap Sampler® passive groundwater sampling method. These procedures describe steps for dedicated and non-dedicated systems.

Pre-Sampling Activities

1. Well location maps, construction information, keys and sampling equipment should be assembled and transported to the site.
2. Water level monitoring and sampling must begin at the monitoring well with the least contamination, generally up-gradient or farthest from the site or suspected source. Then proceed systematically to the monitoring wells with the most contaminated ground water.
3. Check and record the condition of the monitoring well for damage or evidence of tampering. Lay out polyethylene sheeting around the well to minimize the likelihood of contamination of sampling equipment from the soil.
4. Unlock well head. Record location, time, date, and appropriate information in a field logbook or on the groundwater sampling log.
5. Remove inner casing cap.
6. Monitor the headspace of the monitoring well at the rim of the casing for volatile organic compounds (VOC) with a photo-ionization detector (PID) or flame ionization detector (FID) and record in the logbook. If the existing monitoring well currently has or has a history of positive

headspace readings, then the sampling must be conducted in accordance with the Health and Safety Plan.

7. Measure the depth to water (water level must be measured to nearest 0.01 feet) relative to a reference measuring point on the well casing with an electronic water level indicator or steel tape and record in logbook or groundwater sampling log. If no reference point is found, measure relative to the top of the inner casing, then mark that reference point and note that location in the field logbook. Record information on depth to ground water in the field logbook or groundwater sampling log. Measure the depth to water a second time to confirm initial measurement; measurement should agree within 0.01 feet or re-measure.
8. Check the available well information or field check for the total depth of the monitoring well.

Deployment Activities

Selection of the deployment depth within the screen interval is dependent on site specific DQO's. If depth-specific monitoring is required, multiple samplers may be deployed at intervals appropriate for the sampling objective. If previous vertical profiling of a well has been conducted, a selected single deployment depth may be chosen based on the sampling objective. For example, previous data show the bottom three feet of a well have historically contained the highest contaminant concentration; deployment at this depth could be selected based on an objective to sample the highest known concentration within stratified wells. Alternatively, if a well is not stratified, a mid-screen deployment may be appropriate.

Sample zones within a well may be isolated using a packer or baffle device to limit in-well mixing (Britt, 2006; Britt and Calabria, 2008). These can be attached to the Snap Sampler® trigger line or deployed separately. Installation of an upper baffle designed to isolate the unscreened well casing or well headspace may be desired. The upper baffle will limit mixing of "stagnant" casing water

with screen-interval water, an/or gas exchange with the headspace air.

1. Remove the Snap Sampler bottle(s) from its package.
2. Turn the translucent (PFA) vial cap on each end of the bottle slightly to release the O-ring (the o-ring may tend to stick on the glass of the vial if the o-ring is not loosened before trying to set the sampler).
3. Insert the bottle into the upper end of the sampler as shown in Figure 2.

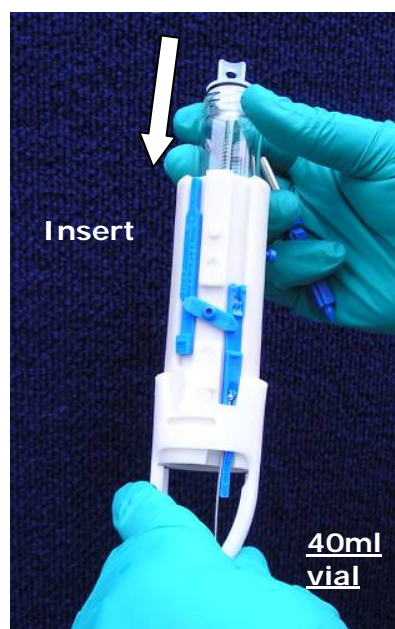


FIGURE 2

4. Place the sampler connector onto each end of the sampler; turn clockwise to align the set pins/screw; then gently tighten the set screw with the Snap Driver Tool (Figure 3).

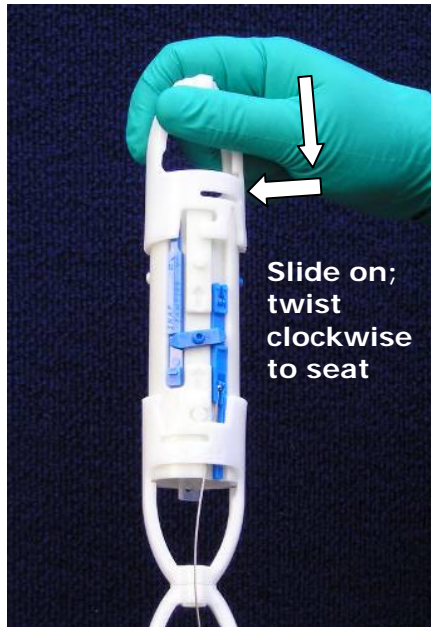


FIGURE 3

5. Pivot the vial cap (Snap Cap) into its seat with the Snap driver. Push up the retainer pin through the lower hole in the vial cap. Repeat for all Snap Caps (Figure 4). If an O-ring should dislodge from its seat during setting, remove the sample bottle and carefully replace it in the o-ring groove; repeat setting procedure.

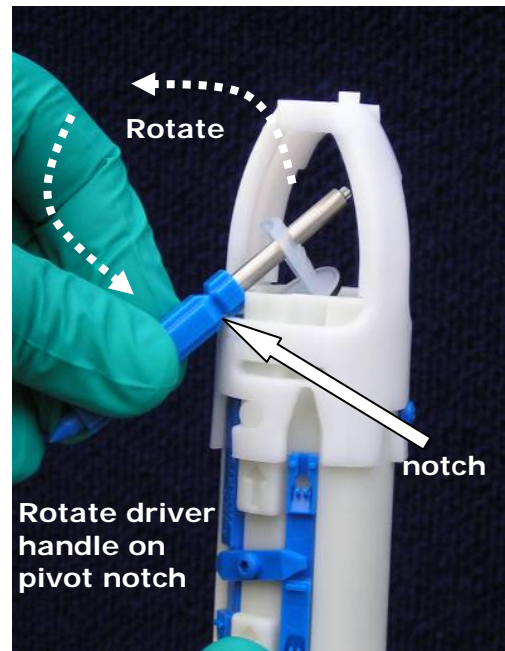


FIGURE 4

6. For the manual trigger, feed ball-fitting end of trigger cable through lower release pin groove; click tube fitting into connector (Figure 5).

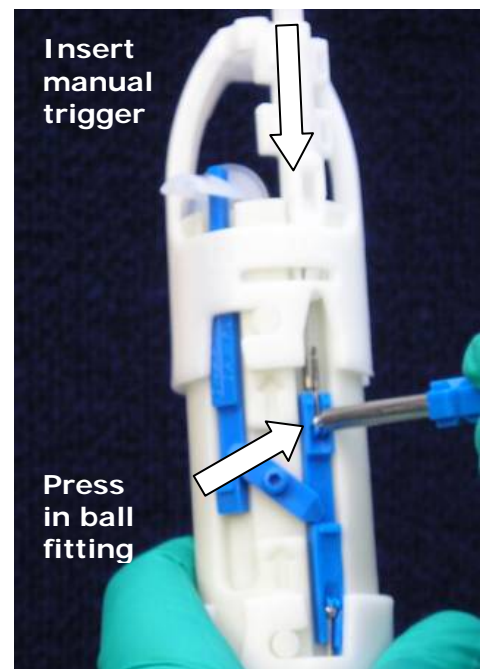


FIGURE 5

7. Press in the ball fitting to attach to lower release pin (Figure 5).

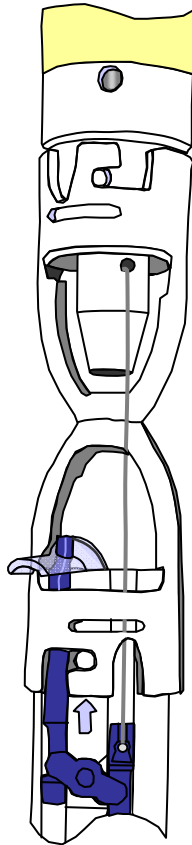


Figure 6

8. For the electric or pneumatic trigger system, attach the wireline from the plunger (Figure 6).

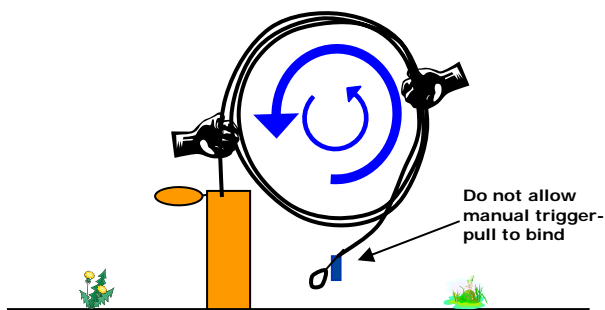


Figure 7

9. Deploy to selected depth with trigger cable/tubing and attach to well head docking station (Figure 7, Figure 8).



FIGURE 8

10. Additional Snap Samplers® can be deployed with separate trigger tubing cables or in series with a single trigger. If separate triggers are used, the ID tags should be marked at the surface for later reference.
11. The recommended minimum deployment period is two weeks. There may be hydrogeologic conditions where a shorter deployment is possible, but two weeks would generally assure a return of the well to its steady-state condition (Vroblesky, 2001a, 2001b).
12. The Snap Sampler® can be deployed for extended periods. It is suggested that quarterly or semi-annual sampling can be done with one mobilization per event, with one set of bottles collected and the following event's bottles deployed immediately afterward. With this

approach all equipment is stored in the well and no special deployment activities are required in advance of routine monitoring.

Sample Collection Activities

When the deployment interval is completed, the sampler should be triggered from the well head without disturbing the sampler position. For the manual trigger, the cable end should be pulled with sufficient force to move the cable up the tubing. Depending on the length of the cable, closure of the samplers usually can be felt through the trigger line when the samplers trip. If more than one triggering line is present, closure should proceed from the deepest to the shallowest sampler position to limit capture of sediment re-suspended by closure of the first sampler.

After the sampler is triggered and retrieved, the upper connector should be removed by loosening the retainer screw and turning the connector. The bottom connector piece does not need to be disassembled to remove the bottles.

While the bottles should not leak with reasonable handling, they should not be agitated (to check for headspace, for example) until after the screw caps are tightened. Under most circumstances there will be no air in the vials at retrieval. However, some field conditions, including deep groundwater, natural effervescence, or other causes, may allow some small air bubbles to be present in the bottle or on the spring when retrieved. This is not a concern if the air was entrained while deployed. Air adhering to the vial during deployment would be in equilibrium with the sample water upon sampler closure. Therefore it is not "headspace air" into which sample VOCs could volatilize. Deployment air could be attached to the spring or cap, and should not be larger than 1-2 mm upon retrieval. Pankow (1986) showed that small headspace air from these or other causes do not substantially impact results for most common volatiles. If air bubbles are larger than 5 mm before placing the screw cap, or water is clearly leaking from the vial, the sample may not have sealed properly and should be discarded. (A failure rate of less than 1% should be anticipated).

There are no special laboratory preparation procedures for Snap Sample bottles. The bottles can be analyzed using common 40-ml autosamplers. The spring inside the VOAs is PFA Teflon-coated and will deflect out of the way of the extraction needle during insertion.

The appendices include step-by-step instructions for deployment and bottle preparation procedures.

Appendix A contains step-by-step field procedures for deployment of both 40 ml Snap Sampler VOAs and 125 ml Snap Sampler POLY bottles.

Appendix B contains step-by-step procedures for preparation of both 40 ml Snap Sampler VOAs and 125 ml Snap Sampler POLY bottles.

DECONTAMINATION PROCEDURES

The electronic water level indicator probe/steel tape, the water-quality field parameter sensors and Snap Sampler® groundwater sampling device should be decontaminated by the following procedures:

1. The water level meter will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water.
2. Water quality field parameter sensors with distilled water between sampling locations where utilized. No other decontamination procedures are necessary or recommended for these probes since they are sensitive. After the sampling event, the sensors must be cleaned and maintained per the manufacturer's requirements.
3. The Snap Sampler® and trigger tubing must be pressure-sprayed or bristle-brush scrubbed with soapy water, tap water, and distilled water. Depending on the condition of the Snap Sampler®, the release pin mechanism may need to be disassembled to effectively clean the pins and grooves. Disassembly can be accomplished by removing the lever screw.

FIELD QUALITY CONTROL

Quality control (QC) samples must be collected to verify that sample collection and handling procedures were performed adequately and that they have not compromised the quality of the groundwater samples. The appropriate EPA or other appropriate program guidance must be consulted in preparing the field QC sample requirements for the site-specific Quality Assurance Project Plan (QAPP).

There are five primary areas of concern for quality assurance (QA) in the collection of representative groundwater samples:

1. Obtaining a groundwater sample that is representative of the aquifer or zone of interest in the aquifer. Verification is based on the field log documenting that the field procedures were followed appropriately during sample deployment and collection.
2. Ensuring that the sampling devices are made of materials, and utilized in a manner that will not interact with or alter the analyses.
3. Ensuring that results generated by these procedures are reproducible; therefore, the sampling scheme should incorporate co-located samples (duplicates).
4. Preventing cross-contamination. Sampling should proceed from least to most contaminated wells, if known. Field equipment blanks should be incorporated for all sampling, and decontamination of the equipment is therefore required.
5. Properly preserving, packaging, and shipping samples.

All field QC samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The chain-of custody procedures for the QC samples will be identical to the field groundwater samples. The following are QC samples that should be collected during the sampling event:

Field duplicates	1 per 20 samples
Matrix spike	1 per 20 samples
Matrix spike dup.	1 per 20 samples
Equipment blank	per requirements
Trip blank (VOCs)	1 per sample cooler
Temperature blank	1 per sample cooler

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site Health and Safety Plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phase through the use of appropriate personal protective equipment.

Depending on the type of contaminants expected or determined in previous sampling efforts, the following safe work practices should be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and incidental ingestion of sample water.
2. Use protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.
2. Pre-survey the well head space with an appropriate device as specified in the site Health and Safety Plan.
3. If monitoring results indicate elevated organic constituents, sampling activities may be conducted in elevated protective equipment (e.g. level C protection). At a minimum, skin protection will be afforded by disposable protective clothing, such as

Tyvek®, appropriate gloves and face protection.

General practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when field acidifying VOA bottles, hydrochloric acid fumes may be released and should not be inhaled. Acid should not contact skin, eyes, or unprotected clothing.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once groundwater sampling has been completed.

These activities include, but are not limited to the following:

1. Ensuring that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
2. Processing all sample paperwork, including copies provided to the appropriate sample handling and tracking facility.
3. Compiling all field data for site records.
4. Verifying all analytical data processed by the analytical laboratory against field sheets to ensure all data has been returned to sampler.

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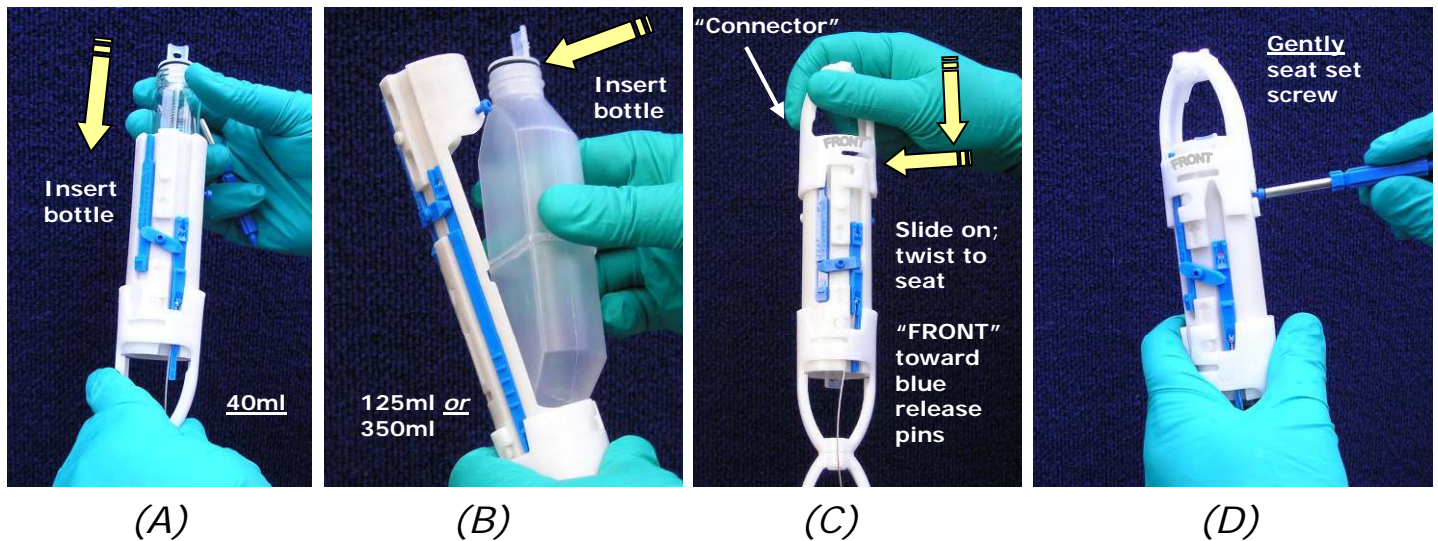
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SNAP SAMPLER DEPLOYMENT (PAGE 1 OF 2)

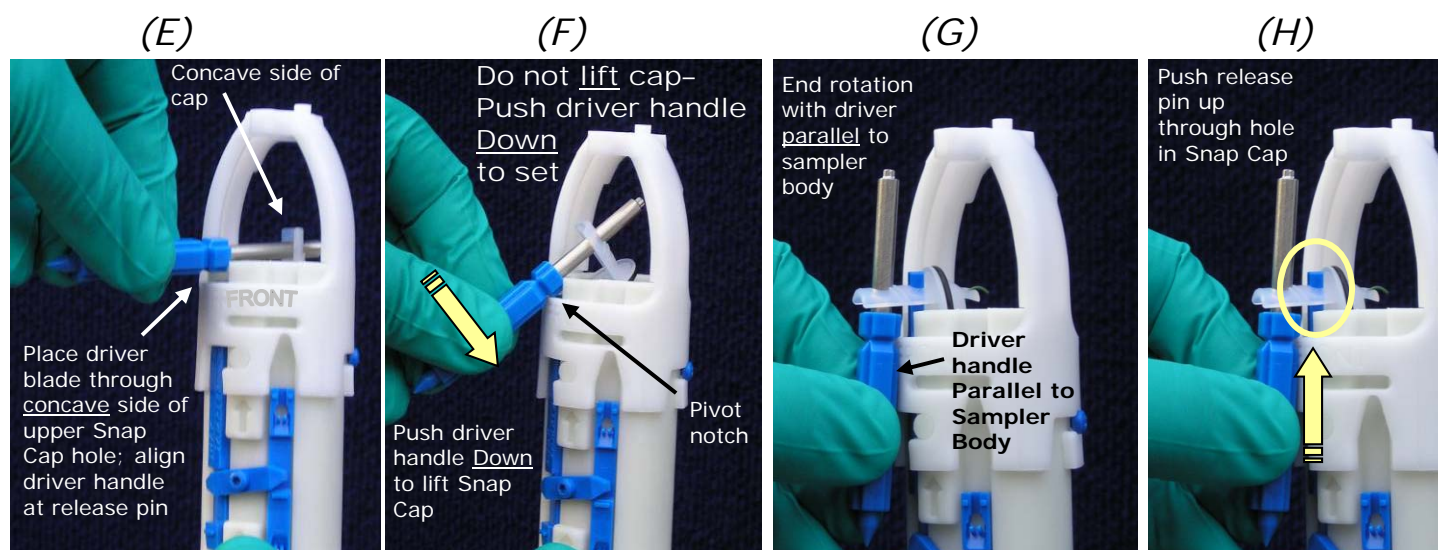
INSERTING AND SECURING BOTTLES

Version 01-10



- A) Insert 40 ml VOA into top of 40 ml Snap Sampler...
- B) Insert 125ml or 350ml POLY into back side of 125 ml Snap Sampler.
- C) Slide twist-on “Connector” over sampler and twist clockwise to seat—the word “FRONT” should appear above the blue release pins.
- D) Gently secure connector with blue set screw.
- E) Set All **Bottom** Snap Caps First, then Top Snap Caps. Insert Snap Driver blade into the upper hole of the concave side of Snap Cap; align driver over the release pin that you will set the Snap Cap.
- F) Push down on Snap driver handle to lift Snap Cap; grasp driver or use thumb to push driver down; keep fingers clear of the under-side of the driver tool.
- G) Pivot on the notch in the driver handle until driver handle is flush/parallel with sampler body and Snap Cap is in its seat.
- H) Push release pin up through lower hole in the Snap Cap; repeat “E” through “H” for each Snap Cap and all Samplers.

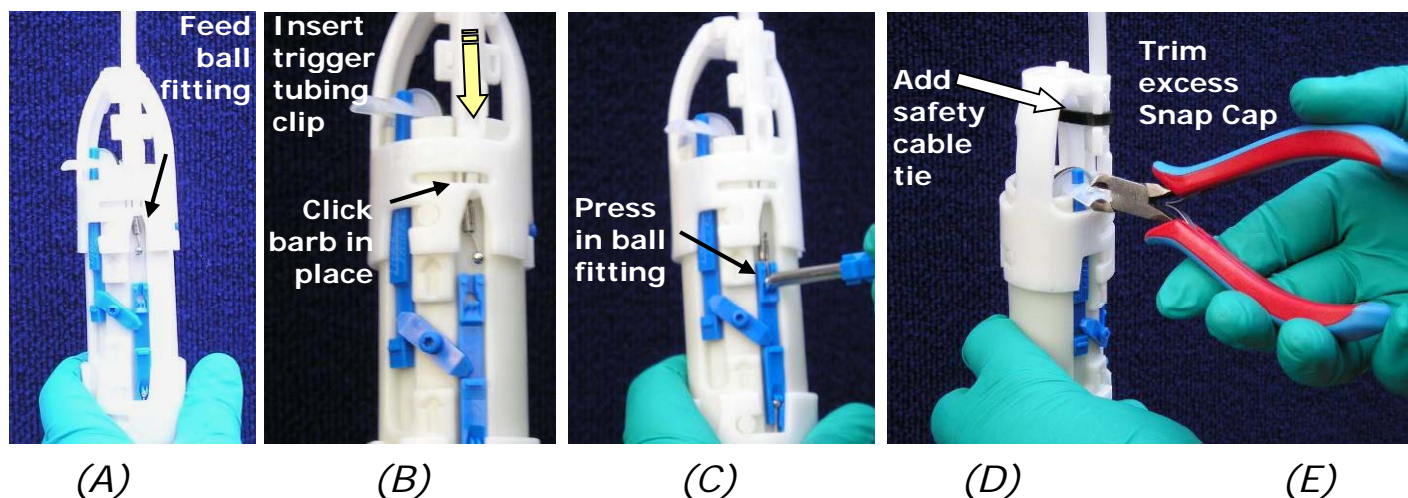
SETTING SNAP CAPS



SNAP SAMPLER DEPLOYMENT (PAGE 2 OF 2)

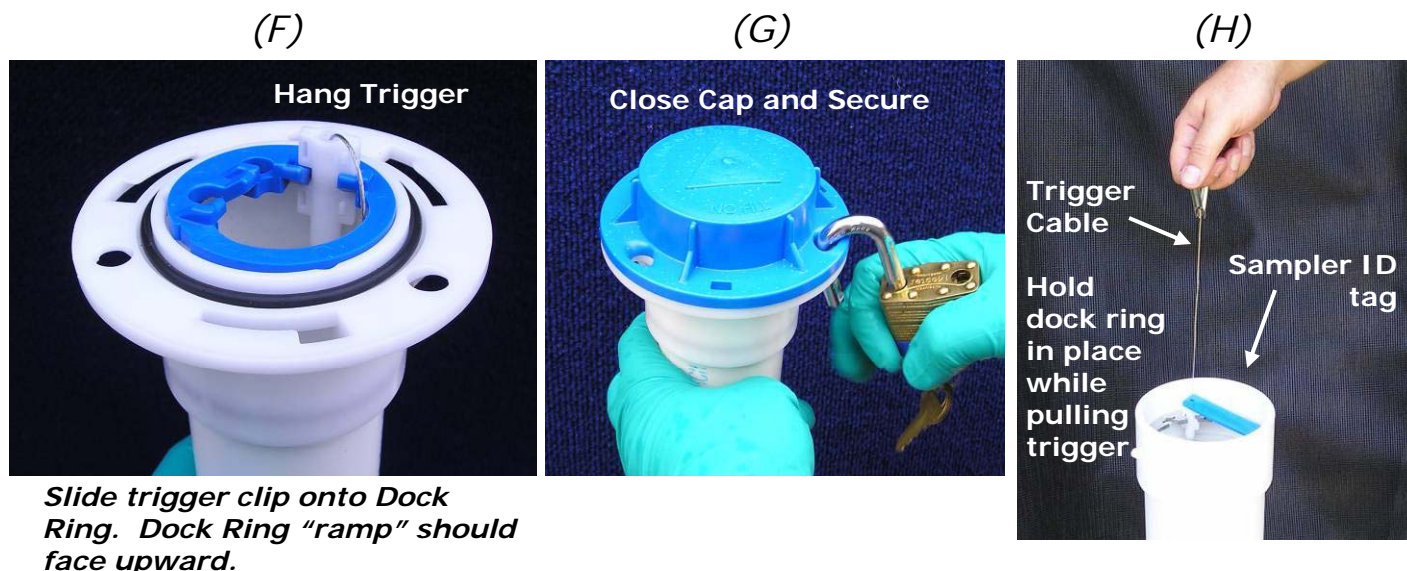
ATTACHING MANUAL TRIGGER

Version 01-10



- A) Insert trigger in right/upper release pin groove—feed ball fitting first.
- B) With **trigger barb facing out**, insert trigger until barb **clicks** into position.
- C) Press ball fitting into release pin using Snap Driver Tool.
- D) Attach safety cable tie.
- E) Trim protruding Snap Caps between ribs (required for smaller diameter wells). Where more than one sampler is attached to one trigger, **connect ball-end connector cables between each sampler** (not shown).
- F) Lower Sampler to depth; seat trigger clip into ramp on Dock Ring.
- G) Close and lock well cap.
- H) To sample, **pull trigger cable while holding Dock Ring in place**; remove trigger from dock and retrieve samplers.

WELL HEAD DOCK ATTACHMENT



SNAP SAMPLER BOTTLE PREPARATION

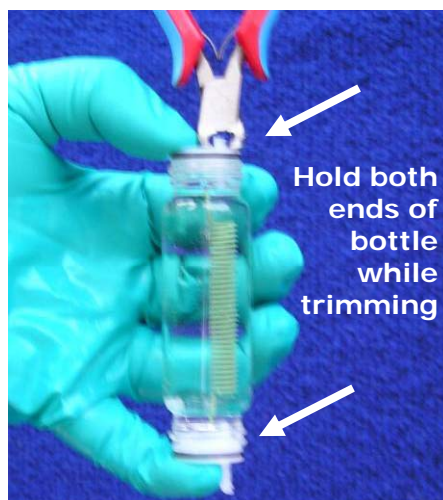
40 ML VOA

TRIM SNAP CAPS

Version 01-10



(A)



(B)



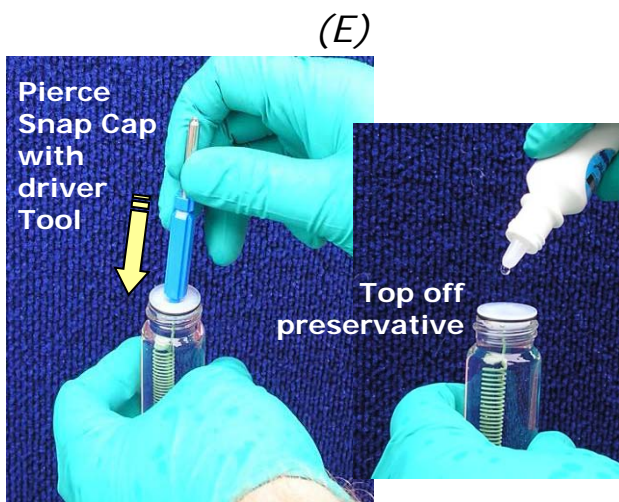
(C)

- A) Snap Sampler VOA, removed from Snap Sampler.
- B) **[UNPRESERVED]** Carefully trim Snap Caps as flush as possible. To trim first Snap Cap, hold ends with finger and thumb; clip carefully--making sure not to dislodge seal. Carefully screw on first septa cap. Trim second Snap Cap; clip carefully--making sure not to dislodge seal; screw on second septa cap, then re-tighten both septa caps to secure.
- C) Prepared, unpreserved bottle.
- D) **[PRESERVED]** After securing the first end of the Snap Cap, trim the second Snap Cap; add 2-3 drops of preservative to the cavity in the Snap Cap.
- E) **[PRESERVED]** Pierce the Snap Cap membrane with the pointed end of the Driver Tool to allow preservative to mix with the sample; add preservative to form a meniscus, then secure the second septa cap.
- F) Prepared, preserved bottle.

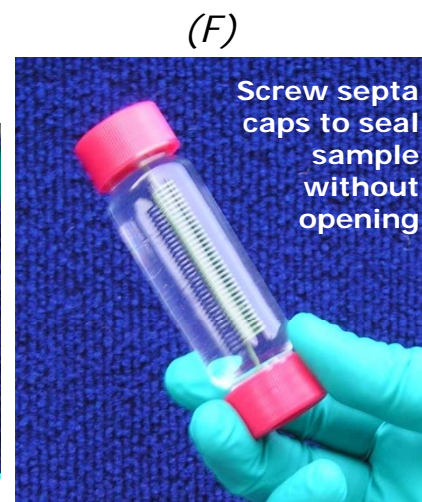
ADD PRESERVATIVE (AS REQUIRED)



(D)



(E)



(F)

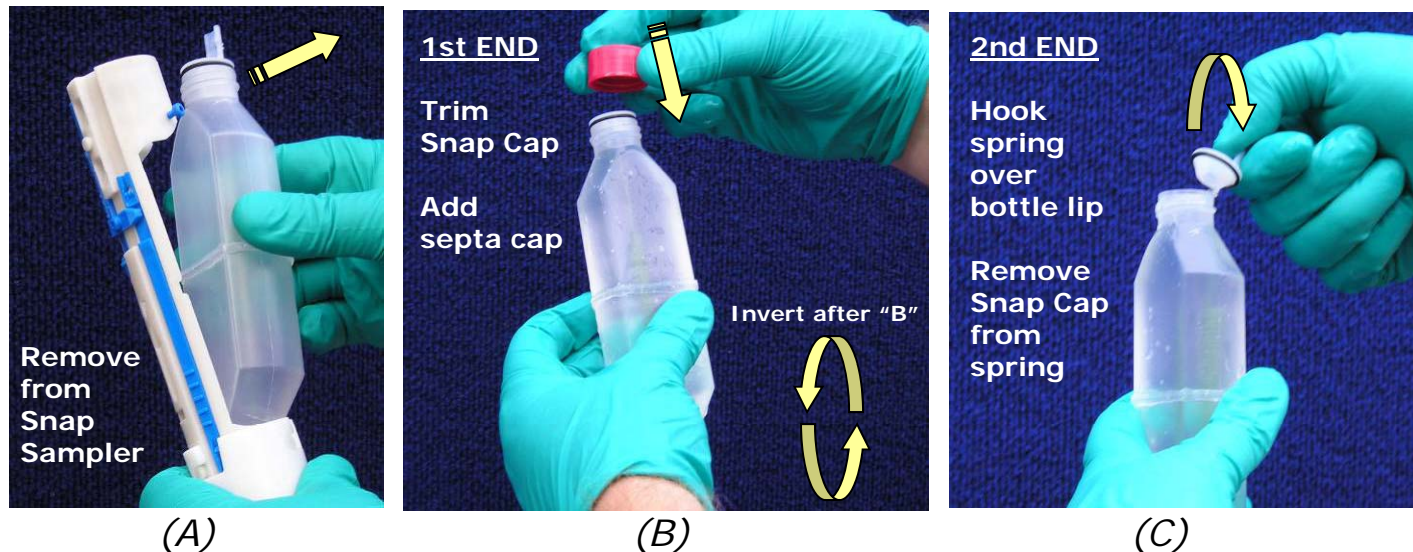
SNAP SAMPLER BOTTLE PREPARATION

125 ML POLY

**(FOR ANALYTES WHERE AIR EXPOSURE AFTER COLLECTION IS NOT A CONCERN,
OTHERWISE FOLLOW PREPARATION PROCEDURE FOR 40 ML VOA ON REVERSE)**

TRIM/REMOVE SNAP CAPS

Version 01-10



- A) Remove Snap POLY Bottle from Snap Sampler.
- B) Trim one Snap Cap (see step "B" on reverse); secure septa cap on first end (you will remove it in step "E" below). **This is an important step or you will lose your sample in step D!**
- C) Invert bottle and remove second Snap Cap from the spring by hooking the internal Spring over the lip of the bottle.
- D) Using lip of septa cap, lift the spring hook form the edge of the bottle and release into the bottle; secure cap on this end of bottle.
- E) Re-invert the bottle; remove septa cap; remove the Snap Cap and spring.
- F) Add preservative (if required), secure septa cap.
- G) Prepared bottle

REMOVE SPRING

